MANAUS • PROJETO SHIFT • HAMBURG

EMBRAPA / CPAA

UNIHH / IANGBOT

RECUPERAÇÃO DAS AREAS ABANDONADAS

SHIFT-Projekt ENV-23

Rekultivierung degradierter, brachliegender Monokulturflächen in ausgewogene Mischkulturflächen unter besonderer Berücksichtigung bodenbiologischer Faktoren

Förderkennzeichen 0339457A

Jahresbericht 1993

EMBRAPA/CPAA - Universität Hamburg

INHALT

Anmerkung:

In den nachfolgenden Aufsätzen sind Literaturstellen wie üblich mit Autorennamen und Erscheinungsjahr zitiert, die Autoren der Aufsätze dieses Berichts dagegen ohne Jahreszahl und in *kursiver Schrift*.

1. Vorwort

Der Zwischenbericht 1993 wird in einer für derartige Berichte ungewöhnlichen Form und auch in einer ungewöhnlichen Ausführlichkeit präsentiert. Der brasilianische Teil ist in nahezu gleicher Form an die KfA GmbH, Jülich, und an das CNPq, Brasília, gerichtet.

Nach einem kurz gehaltenen, allgemeinen Teil folgen fachliche Einzelbeiträge eines jeden Mitarbeiters im Projekt in deutscher, portugiesischer oder englischer Sprache, die von der Form ähnlich wie Aufsätze in wissenschaftlichen Zeitschriften gehalten sind. Jedem der in sich geschlossenen Beiträge sind Zusammenfassungen vorangestellt, so daß sich der Leser zum einen einen schnellen Überblick über die durchgeführten Arbeiten und Ergebnisse verschaffen, zum anderen sich in den Einzelbeiträgen ein Bild über den Leistungsstand des jeweiligen Arbeitsgebietes machen kann. Thematische Überschneidungen waren bei diesem Konzept nicht zu vermeiden. Dabei können unterschiedliche Interpretationen von Ergebnissen oder andere Akzentsetzungen durchaus Kristallisationspunkte für spätere Ergebnisdiskussionen sein. Zum jetzigen Zeitpunkt wurden Versuche, Ergebnisse der unterschiedlichen Disziplinen fachübergreifend auszuwerten oder im Zusammenhang neu zu interpretieren noch nicht unternommen, da in den meisten Bereichen der derzeitige Auswertungsstand hierfür noch nicht ausreicht.

Wir erwarten, daß ein Gewinn für die Arbeitsgruppe darin besteht, auf ein gemeinschaftlich erarbeitetes Werk blicken zu können, welches zum einen die Motivation zur Weiterarbeit erhält und steigert, zum anderen die Möglichkeit eröffnet, gut gelungene Beiträge weiter auszuarbeiten und zu veröffentlichen. Wir hoffen sehr, daß sich die erhebliche Mehrarbeit, die mit der vorgelegten Art des Berichts für alle Beteiligten verbunden war, auf diese Weise auszahlen wird.

Manaus, den 23. März 1994

Dr. Luadir Gasparotto
Dr. Helmut Preisinger

2. Allgemeiner fachlicher Bericht

Der allgemeine Berichtsteil kann kurz gehalten werden, da die von den einzelnen Mitarbeitern durchgeführten Arbeiten in den fachlichen Einzelbeiträgen im Detail dargestellt werden. Nachfolgend sind lediglich einige Querverbindungen zwischen den Ergebnissen der verschiedenen Arbeitsbereiche herzustellen, auf prinzipielle Schwierigkeiten von Versuchsansätzen hinzuweisen und die Arbeitsschwerpunkte dieses Jahres darzustellen.

Das Jahr 1993 war durch die folgenden Arbeitsschwerpunkte gekennzeichnet (vgl. auch Jahresbericht 1992, 4. Übersicht über die Arbeitsschwerpunkte):

1. **Anlage der 19 ha Versuchsplantage:** u.a. Setzen von Markierungspfählen, Ausheben von Pflanzlöchern, ggf. Grunddüngung ins Pflanzloch, Auspflanzen der mehrjährigen und annuellen Nutzpflanzen;

2. **Planung und Durchführung des Plantagen-Managements:** Lenkung des Wildpflanzenwuchses, Pflege der Nutzpflanzen, Düngung, Bekämpfung von Pflanzenkrankheiten, im Einzelfall Nachpflanzen von eingegangenen Pflanzen, Instandhaltung und Pflege des Wegesystems;

3. **Durchführung biometrischer Messungen an den Nutzpflanzen:** Messung u.a. von Stammdurchmessern, Wuchshöhen, Anzahl von Blüten und Früchten;

4. **Probennahmen für Nährstoffanalysen** von verschiedenen Organen der Nutzpflanzen und für Nährstoffanalysen des Bodens;

5. **Bodenbiologische Studien:** Analyse von Wurzelproben auf VAM-Besiedelung, Analyse von Bodenproben auf VAM-Sporen einschl. Quantifizierung und Klassifizierung, Anfertigung von mikroskopischen Dauerpräparaten von VAM-Sporen, Bestimmung von Infektionseinheiten der VAM in Bodenproben, Produktion von VAM-Inokulum, Anlage einer zusätzlichen Experimentalfläche zur Analyse von Wurzelsystemen der Nutzpflanzen, Analyse der räumlichen Struktur der Wurzelsysteme ausgewählter Nutzpflanzen;

6. **Phytomedizinische Untersuchungen:** Kontinuierliche Beobachtung aller Nutzpflanzen sowie Bekämpfung von auftretenden Pflanzenkrankheiten durch Pilze, Insekten u.a., Dokumentation der Schäden und der Wirkungen von

Bekämpfungsmaßnahmen, in Einzelfällen: Untersuchung von Kalamitäten an Wildpflanzen;

7. **Entomologische Studien:** Vergleich des räumlich-zeitlichen Auftretens von Insektengruppen in den verschiedenen Pflanzsystemen der Plantage, im Sekundär- und Primärwald, Einsatz unterschiedlicher Fangmethoden, Beobachtung des Phytophagen-Befalls an Nutz- und Wildpflanzen, Katalogisierung und vorläufige Identifizierung der Insekten (vor allem auf Ordnungs-Ebene);

8. **Vegetations- und standortkundliche Untersuchungen:** quantitative Analyse von Wuchsformentypen in den 90 Parzellen des Versuchs zur Indikation von Standortunterschieden, vollständige Analyse der Flora von 71 Parzellen des Versuchs, Identifizierung der Arten und Anlage einer Referenzsammlung der Pflanzen der Sekundär- und der spontanen Vegetation, Gradientenanalysen mit Hilfe unterschiedlicher statistischer Methoden;

9. **Ökonomische Analyse:** Kalkulation der Kosten, die die einzelnen Nutzungssysteme einem Produzenten verursachen würden, aus den derzeit verfügbaren Daten;

10. **Meteorologische Messungen:** Messung und Auswertung der folgenden Parameter auf der Versuchsfläche des CPAA[1]: Niederschlag, Lufttemperatur, relative Luftfeuchte, Sonnenscheindauer, Verdunstungskapazität der Luft, Windgeschwindigkeit und Bodentemperaturen.

Mit der Durchführung der genannten Arbeiten konnte der Arbeitsplan eingehalten werden.

Eines der Grundziele des Projekts ist die Erprobung der Wirkung von VA-Mykorrhizapilzen auf Nutzpflanzen unter praxisnahen Bedingungen in der tropischen Landwirtschaft. Dabei wurden Pilzstämme appliziert, die im Labormaßstab eine hohe Wirksamkeit bezüglich Wachstums-Förderung und Resistenzeigenschaften der Pflanzen bewiesen hatten. Diese Wirksamkeit bestätigte sich in der Phase der Pflanzenanzucht für die Mehrzahl der Nutzpflanzen: So waren z.B. die Auspflanzverluste bei den inokulierten Pflanzen deutlich niedriger als bei den Kontrollpflanzen (s. *Idczak*). Ob die Inokulation die Pflanzenentwicklung nur in der Jugendphase fördert oder auch später

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[1] Die Daten stammen von der Station des CPAA, ca. 2 km von der SHIFT-Versuchsfläche entfernt gelegen. Die neu gekaufte meteorologische Station wurde inzwischen installiert und hat am 10.3.1994 ihren Betrieb aufgenommen.

anhält, müssen die weiteren Beobachtungen und Messungen zeigen. Eine Schwierigkeit wird darin bestehen, die Kausalität zwischen dem Faktor "Inokulation" und Wachstumsparametern oder dem Resistenzverhalten gegenüber Pathogenen nachzuweisen, denn die Nutzpflanzen entwickeln sich im Feld unter dem Einfluß von zahlreichen, örtlich verschiedenen Standortfaktoren, deren Differenzen eine z.T. größere Wirkung auf die Pflanzen haben dürften als die Inokulation mit Mykorrhizapilzen. Um diese Zusammenhänge bei der späteren Endauswertung abschätzen zu können, werden ökologische Gradienten der Experimentalfläche untersucht (*Preisinger, Siqueira & Coelho; Tavares, Preisinger & Martins*). Mit dem Sprung vom Labormaßstab in den Maßstab der landwirtschaftlichen Nutzfläche hat die Mykorrhizaforschung die alleinige Untersuchung von Funktionszusammenhängen im cm- bis μm-Maßstab verlassen und muß sich zusätzlich mit Funktionen und Strukturen im m- bis 100m-Bereich befassen: Die Frage, inwieweit kurzlebige VAM-inokulierte Nutzpflanzen wie Mais im Feld für die Infizierung ausdauernder Nutzpflanzen eingesetzt werden können, ist ein Beispiel dafür ("nurseplant-effect", s. *Idczak*). Die Untersuchungen zur räumlichen Struktur der Wurzelsysteme ausgewählter Nutzpflanzen und Beispiele aus der Sekundärvegetation Ende letzten Jahres sind im Zusammenhang mit diesen Fragestellungen zu sehen (s. *Voß*). Eine fast unüberwindliche Schwierigkeit für die Beurteilung des VAM-Sporenpotentials im Boden ist das völlige Fehlen von Kennnissen über die Muster der Sporenverteilung im Substrat und über Unterschiede in der Besiedelung der Wurzeln von Wildpflanzen derselben Art, bezogen z.B. auf die Parzellengröße des Versuchs (48 x 32 m^2). Boden- und Wurzelprobennahmen konnten daher nicht in einem räumlichen Abstand, der dem Verteilungsmuster der Mykorrhizapilze im Boden angepaßt ist entnommen werden, sondern allein aufgrund praktischer Erfordernisse: Welche Proben-Anzahlen können arbeitsmäßig bewältigt werden, bezogen auf interessierende Flächeneinheiten (Parzellen- oder Untersuchungsflächen-Größe)? Die großen Unterschiede, die die Wurzel- und Bodenproben aufweisen, spiegeln diese Unsicherheiten wider (vgl. *Idczak* und *Figueiredo & Oliveira*). - Um Hinweise dafür zu gewinnen, welche Rolle VA-Mykorrhiza für die Sekundär- und spontane Vegetation spielt und ob Monokulturplantagen-Standorte hiervon tatsächlich signifikant abweichen (s. Feldmann & Lieberei 1991), werden in diesem Jahr häufigere Pflanzenarten des Sekundärwaldes und der Plantagenstandorte auf Mykorrhizabesiedelung untersucht werden.

Sowohl für die Bodenbiologie als auch für die Vegetationskunde ist die Wahl eines geeigneten Untersuchungsmaßstabs ein Problem. Bisher ist wenig über die räumlichen Muster bekannt, die die Arten des Sekundärwaldes der Versuchsfläche bilden. Beispielgebend wird die 1 ha Sekundärwald-Vergleichsfläche am Rande der Versuchsplantage in diesem Jahr daraufhin vegetationskundlich untersucht werden. Die 1993 durchgeführten Untersuchungen befaßten sich ausschließlich mit der Vegetation der Versuchsplantage. Die Ergebnisse zeigen, daß eine Indikation von Standortunterschieden und -gradienten schon mit einfachen Aufnahmeverfahren möglich ist. Die Methodik wurde im Dezember 1993 zusätzlich in den Feldversuchen des "Capoeira-Projekts" (ENV-25) erprobt. Die beiden Datensätze sollen vergleichend analysiert werden bezüglich der Wirkungen unterschiedlicher Nutzungsformen und -dauer auf die spontane Vegetation. Die bisher durchgeführten Vegetationsuntersuchungen auf der Versuchsfläche belegen die Existenz eines Vegetations- und Standortgradienten von Block a nach Block e. Die bisher vorliegenden Ergebnisse der biometrischen Messungen an den Nutzpflanzen deuten in die gleiche Richtung (s. Moraes; Neves & Martins). Dagegen ließ das VAM-Sporenpotential im Boden (univariate statistische Auswertung von 30 Bodenproben) keinen Gradienten erkennen (vgl. *Idczak*). Als Vorbereitung für die bodenkundlichen Untersuchungen zu den Wasser- und Nährstoffverhältnissen auf der Versuchsfläche, deren Beginn für dieses Jahr geplant ist, wurden die z.Z. zur Verfügung stehenden Daten zur Topographie (Nivellement und Höhenlinien-Karte) und zur Nährelemente-Verteilung in der Fläche ausgewertet (s. *Tavares, Preisinger & Martins*).

Sowohl die bodenbiologischen als auch die vegetations- und standortkundlichen Arbeiten sind *synökologische Untersuchungen*, und zwar zu den Wechselwirkungen zwischen

- höheren Pflanzen und Boden-Mikroorganismen und
- Nutzpflanzen- und Wildpflanzeninventar und maßgeblichen Standortfaktoren (des Bodens, der Vornutzung und des aktuellen Managements).

Demgegenüber handelt es sich bei den Arbeiten zur Biomasseproduktion und zu Nährelemtentgehalten an ausdauernden Nutzpflanzen (s. *Schmidt*) um Untersuchungen zur *Autökologie* der Nutzpflanzen-Arten. Die Verbindung zu den erstgenannten Untersuchungen wird dann hergestellt sein, wenn Ergebnisse zum Nährstoffbedarf der Nutzpflanzenarten[2] und zu den ökologischen Amplituden, die diese in Bezug auf die Kombination der Nährelemente aufweisen, vorliegen. Für vergleichende Betrachtungen ist es zwingend erforderlich, einige charakteristische und häufig vorkommende Arten der Sekundärvegetation in gleicher Weise wie die Nutzpflanzen zu analysieren (= Nährelementeverteilung in den Pflanzenorganen). Dahinter steht die Frage nach der prinzipiellen Eignung der eingesetzten Nutzpflanzenarten für eine langfristige Nutzung der Terra-Firme-Standorte.

Die bisherigen Auswertungen der phytomedizinischen Untersuchungen (s. *Gasparotto & Lima*) lassen keine einheitlichen Trends hinsichtlich der Zusammenhänge zwischen

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[2] prognostiziert aufgrund von Hochrechnungen, die auf den Ergebnissen der durchgeführten Nährstoffanalysen beruhen (s. *Schmidt*).

dem Auftreten von Pflanzenkrankheiten und der Inokulation der Pflanzen mit VA-Mykorrhizapilzen bzw. ihrer räumlichen Verteilung erkennen. Die Auswertung der entomologischen Untersuchungen (*Pamplona*) ist an die Identifizierung der gesammelten Insekten gebunden, welche noch einige Zeit in Anspruch nehmen wird. Der hier dargestellte entomologische Berichtsteil beschränkt sich daher vor allem auf die Protokollierung der an den Nutzpflanzen festgestellten Schadinsekten, der dadurch eingetretenen Schäden sowie auf durchgeführte Bekämpfungsmaßnahmen.

Aufgrund der kurzen Zeitspanne seit Anlage der Plantage (1 Jahr) liegen für einige Arbeitsgebiete noch nicht viele oder nur wenige aussagekräftige Daten vor. Das betrifft vorwiegend die biometrischen Untersuchungen und insbesondere die der agroforstlichen Systeme (*Neves & Martins; Moraes*).

Die ökonomische Analyse (*Normando, Martins & Guimarães*) konzentrierte sich vorerst auf die Kosten, die die unterschiedlichen zu testenden Pflanzsysteme verursachen. Die vorgelegten Ergebnisse werden an Aussagekraft gewinnen, wenn aufgrund von Markt-analysen Einnahme-/Ausgaberechnungen durchgeführt und wenn aufgrund von Befragungen von Landwirten der Region die Möglichkeiten des Einsatzes von Mischkultursystemen abgeschätzt werden können.

Dr. Luadir Gasparotto
Dr. Helmut Preisinger

3. Zusammensetzung der Arbeitsgruppe Manaus

Projektkoordination

Dr. Luadir Gasparotto, EMBRAPA/CPAA, Manaus
Dr. Helmut Preisinger, Universität Hamburg

Wissenschaftliche Mitarbeit

1. EMBRAPA/CPAA, Manaus-AM

Dr. Newton Bueno (Pflanzenernährung)
Osvaldo M.R. Cabral (Agrarmeteorologie))
Dr. Acilino do Carmo Canto (Agrarökologie)
Carlos Doza (Agrarmeteorologie)
Dr. Luadir Gasparotto (Phytopathologie)
Rosângela dos Reis Guimarães (Ökonomie)
M. Imaculada P.M. Lima (Phytopathologie)
Jeferson L.V. Macêdo (Kulturtechnik)
Gilvan C. Martins (Statistik)
Dr. Vicente H. de F. Moraes (Physiologie der Kulturpflanzen)
Edinelson J.M. Neves (Agroforstliche Systeme)
Mirza C. Normando (Ökonomie)
Cley D.M. Nunes (Kulturtechnik)
Ana M.S. Pamplona (Entomologie)
M. do Socorro G. Siqueira (Botanik)
Adauto M. Tavares (Vermessung)

2. INPA, Manaus-AM

L.F. Coelho (Botanik)
N.A.F. Farias (Bodenbiologie)
E.M. Figueiredo (Bodenbiologie)
F.W. Moreira (Bodenbiologie)
Dr. L.A. Oliveira (Bodenbiologie)

3. Universität Hamburg

Dr. Elke Idczak (Bodenbiologie)
Ingo Müller (Landwirtschaft)
Dr. Helmut Preisinger (Vegetationskunde)
Petra Schmidt (Agrarbiologie)
Karsten Voß (Bodenbiologie)

4. Fachliche Einzelbeiträge

INHALT

Recultivation of abandonded monoculture areas in Amazonia

R. Lieberei, L. Gasparotto, H. Preisinger & F. Feldmann

Resumo:

Aproveitamento das áreas abandonadas de monocultura na Amazônia
O projeto é referente a um experimento instalado em um plantio de seringueira abandonado, de 17 ha, estabelecido com sistemas de policultivo de espécies selecionadas, principalmente árvores. Com o objetivo de atingir a sustentabilidade, diferentes combinações de culturas e estratégias de manejo da vegetação espontânea serão testados e os sistemas de cultivo serão estabilizados inoculando-se as plantas em espores de fungos micorrízicos. A área experimental foi dividida em 5 blocos, com 18 parcelas cada, para testar 4 sistemas de policultivo comparados com 4 sistemas de monocultivo convencional. Parcelas em pousio serão analisadas para servir de referência. A pesquisa científica está direcionada para a função ecológica dos fungos micorrízicos no ensaio de campo, para as análises dos aspectos funcionais e estruturais da vegetação espontânea devido ao manejo e para a identificação e controle das doenças das plantas. Além disso, estudos econômicos e de aceitação serão conduzidos para determinar se os produtores estão inclinados a aplicar, na prática, os sistemas de cultivo testados.

Summary:

The project concerns an experiment in recultivating a fallow rubber plantation of 19 ha by establishing mixed plantations of selected crops, mainly trees. In order to achieve sustainability, different crop combinations and different strategies for management of the spontaneous vegetation will be tested, and the crop systems stabilized by inoculation of the plants with spores of mycorrhizal fungi. The experimental area was divided into five blocks with eighteen plots each to test four mixed cultivation systems, compared to four conventional monoculture systems. Fallow plots will be analysed for reference. The scientific research is focused on the ecological role of mycorrhizal fungi in the field trial, analysis of the structural and functional traits of the spontaneous vegetation due to management and on identification and control of plant diseases. In addition, economic and acceptance studies will be conducted to find out whether farmers are willing to apply the tested cultivation systems in practice.

1 Introduction

The main objective of the project is to develop an ecologically, socially and economically viable system of agriculture better suited to the humid, tropical conditions of Amazonia than existing production methods. It concerns an experiment in recultivating a fallow rubber plantation by establishing mixed plantations of selected, mainly perennial, crops. The function of trees as reservoirs for nutrients and their role in the recycling of biomass in complex systems has often been demonstrated (e.g. Shubarth 1977, Sioli 1980, Burger 1986). Any scheme to recultivate fallow lands in the Amazon must take particular account of pedological and soil-microbiological factors: as the areas in question were originally taken into cultivation by slash-and-burn of primary forest, the soil structure has been altered. First soil-biological analyses in rubber plantations show a dramatic change in the populations of soil microbes (Feldmann & Lieberei 1992) and increased susceptibility of the plants to stress. In most cases, the lands were also cleared mechanically after burning and subjected to high inputs of pesticides during the cultivation phase (Faßbender 1990).

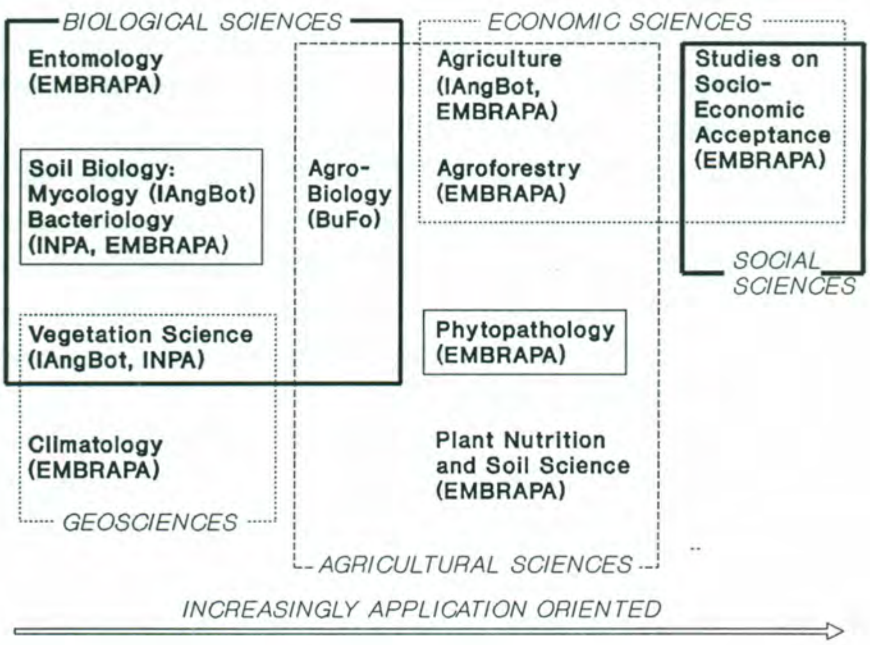

Fig. 1:

Scientific disciplines and institutions involved in the project "Recultivation of abandoned areas ...".

IAngBot = Institut für Angewandte Botanik, Hamburg; BuFo = Bundesforschungsanstalt für Holz- und Forstwirtschaft, Hamburg; EMBRAPA = Empresa Brasileira de Pesquisa Agropecuária da Amazônia, Manaus; INPA = Instituto Nacional de Pesquisa da Amazônia, Manaus

Mycorrhizal fungi can promote the growth and health of crop plants in the humid tropics. There is evidence that young rubber trees (*Hevea sp.*) inoculated with spores of mycorrhizal fungi grow faster and are more resistant to South American leaf blight (*Microcyclus ulei*) compared with reference plants (Feldmann, 1990). But there are also other measures which can be taken to improve plant growth and health in a plantation setting.

In the 19 ha plantation, we intend to test the three following ways of stabilizing crops in different test variants and to analyse the crop systems on a scale close to practical conditions:

1. Inoculation of the plants with spores of mycorrhizal fungi,
2. Testing of different mixed cultivation systems,
3. Experiments on management of the spontaneous vegetation in the crop systems to improve the competitive conditions for the planted crops.

The project has its scientific basis in the field of phytopathology and mycology. However, the operational basis for implementation of the project is much broader: The existing working group is composed of scientists from EMBRAPA, Manaus, the Institute of Applied Botany of Hamburg University, the Federal Research Institute for Timber and Forestry in Hamburg and INPA, Manaus. It covers areas of the disciplines shown in Fig. 1. Basic knowledge has been or is being accumulated in the field of mycology, bacteriology and vegetation science; application-orientedness increases in the direction of the arrow. For this reason, the acceptance studies designed to find out whether farmers in the region are in fact willing to apply the tested cultivation systems in practice are positioned on the far right.

2 Field trial

The experimental area concerns terra firme lands on the EMBRAPA site to the north of Manaus, which were first cleared of primary forest about ten years ago to make way for a rubber plantation. The plantation was abandoned soon after. In August/September 1992, the approximately eight-year-old secondary forest which had evolved in the meantime was cleared and burnt in the traditional manner. The plantation is now established, some short lived plants already being harvested (beans, maize, fruits of papaya).

2.1 Planted crops and plantation systems

Fourteen species of useful plants are planted in the experimental field (table 1). Four different mixed cultivation systems (systems 1-4, see table 2) and four conventional monocultures (systems 6-9) are to be compared in the field trial. System 5 is land which was prepared in the same way as the other systems and then left to follow its own course. Perennials, short-term crops for planting between the rows and cover plants are being used in the systems. The choice of crops was based largely on current marketing prospects.

System 1 is a comparatively intensive cultivation system with little space left between the rows. More space was left between rows in systems 2 and 3, which can be used for growing short-term crops in the first year. In practice, this would help farmers survive the first years after establishment of the plantation, during which the longer-lived species are not generating any income. System 4 is the most "extensive" of the test systems. The species planted produce timber. Secondary vegetation is tolerated between the trees. In systems 1-3 and in monocultures 6-8, on the other hand, a cover plant (*Pueraria phaseoloides*) was sown.

2.2 Plantation systems and test variants implemented

The nine plantation systems described are being established in different test variants (table 3). In systems 1-3, plants inoculated with mycorrhizal fungi are compared to control plants. The fungi were applied to all plants cultivated in system 4, but not to the monocultures. The fertilization variants include zero fertilizer, 30 % and 100 % of the recommended dose for the respective species. That gives a total of n=54 possible test variants. In our experiment we are implementing the 18 variants which promise to give the most meaningful comparisons.

2.3 Experimental area and layout of the field test

In the field test the 18 variants are being laid out in five separate, i.e. repeat blocks. The position of the variants within the blocks is completely randomized. The plots have an area of 48 x 32 m^2 each. The arangement of the plants in the four mixed culture systems is shown in table 4. The layout of the plots is determined by the elongated, irregular shape of the experimental area (see Fig. 2). A 100 x 100 m^2 patch of secondary forest was left standing at the edge of the area for comparative studies of the secondary vegetation.

4 References

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Table 1: List of species planted

Common name	Scientific name	Plant family	Use
Seringueira	Hevea spp.	Euphorbiaceae	Rubber production, oil production from seeds
Cupuaçu	Theobroma grandiflorum	Sterculiaceae	Pulp (juice,ice, dessert), pods (chocolate)
Pupunha	Bactris gasipaes	Arecaceae	Fruit, palmito, fodder (leaves), food colourings (fruitflesh), weaving material
Castanha do Brasil	Berthollecia excelsia	Lecythidaceae	Brazil nuts, timber
Urucum	Bixa orellana	Bixaceae	Dyestuffs sunscreens
Cocos	Cocos nucifera	Arecaceae	Oil, copra, coconut milk, feeding stuffs (oil cake), weaving material, fibres, construction timber, particle board
Citrus	Citrus sinensis	Rutaceae	Fruit, oil, pectin
Paricá	Schizolobium amazonicum	Caesalpiniaceae	Timber, charcoal
Mogno	Swietenia macrophylla	Meliaceae	Timber
Andiroba	Carapa guianensis	Meliaceae	Timber, oil
Mamão	Carica papaya	Caricaceae	Fruit, papain, carpain, feeding stuffs
Mandioca	Manihot esculenta	Euphorbiaceae	Starch, vegetables from the leaves
Feijão	Vigna sinensis	Fabaceae	Green fodder, starch
Milho	Zea mays	Poaceae	Starch, edible oil, feeding stuffs
Puerária	Pueraria phaseoloides	Fabaceae	Cover crops

Table 2:
Useful plants and plantation systems

	Plantation systems									
	mixed cultivations				f	monocultures				
	1	2	3	4	5	6	7	8	9	
Seringueira	*		*	*		*				perennial useful plants
Cupuaçu	*	*	*				*			
Pupunha	*	*						*		
Castanha do Brasil		*								
Urucum		*								
Côcos			*							
Citrus			*						*	
Paricá			*	*						
Mogno				*						
Andiroba				*						
Mamão	*									short lived useful plants
Mandioca		*	*							
Feijão			*							
Milho			*							
Puerária	*	*	*			*	*			cover crops
spontan. vegetation				*	*			*	*	

f = fallow (for comparison)

Table 3:
Plantation systems and test variants applied

n = 54	0 fertilizer		30% fertilizer		100% fertilizer		
	-myc.	+myc.	-myc.	+myc.	-myc.	+myc.	
system 1			*	*	*	*	mixed
system 2			*	*	*	*	culti-
system 3			*	*	*	*	vation
system 4				*			
system 5	*						fallow
system 6					*		
system 7					*		mono-
system 8					*		culture
system 9					*		

- myc. = not inoculated with spores of mycorrhizal fungi
+ myc. = inoculated with spores of mycorrhizal fungi

Table 4:

Layout of the four mixed cultivation systems

```
System   I:        4     2,5    2,5    2,5    2,5    2,5    2,5    2,5
                -----S-----M-----P-----M-----C-----M-----P-----M-->
                    4|    3|    2|    3|    6|    3|    2|    3|
                     S     M     P     M     C     M     P     M
                + Pueraria as cover crop

System  II:        4     4     4     4     4     4     4     4     4
                -----B-----U-----C-----P-----B-----U-----C-----P-->
                    7|    4|    7|    2|    7|    4|    7|    2|
                     C     U     B     P     C     U     B     P
                + Maniok between the rows + Pueraria as cover crop

System III:        4     5     5     7     6     5     5     7     4
                -----S-----C-----CP----Z-----S-----C-----CP----Z--->
                    4|    7|    8|    5|    4|    7|    8|    5|
                     S     PC    CP    Z     S     PC    CP    Z
                + Maniok, maize, Cowpea, + Pueraria as cover crop

System  IV:          4        10        10        10        10       4
                -------S--------MG-------PC-------A-------S-------->
                      4|        7|       4|       7|       4|
                       PC        A        S        MG       PC
                + spontaneous vegetation between the rows
```

Legend:

```
----  distances between the rows [m]
__    distances between the plants in a row [m]
```

Abbreviations of the plant species:
S = Seringueira, C = Cupuaçu, P = Pupunha, B = Castanha-do-Brasil,
U = Urucum, K = Cocos, Z = Citros, PC = Paricá, Mg = Mogno,
A = Andiroba, M = Mamão

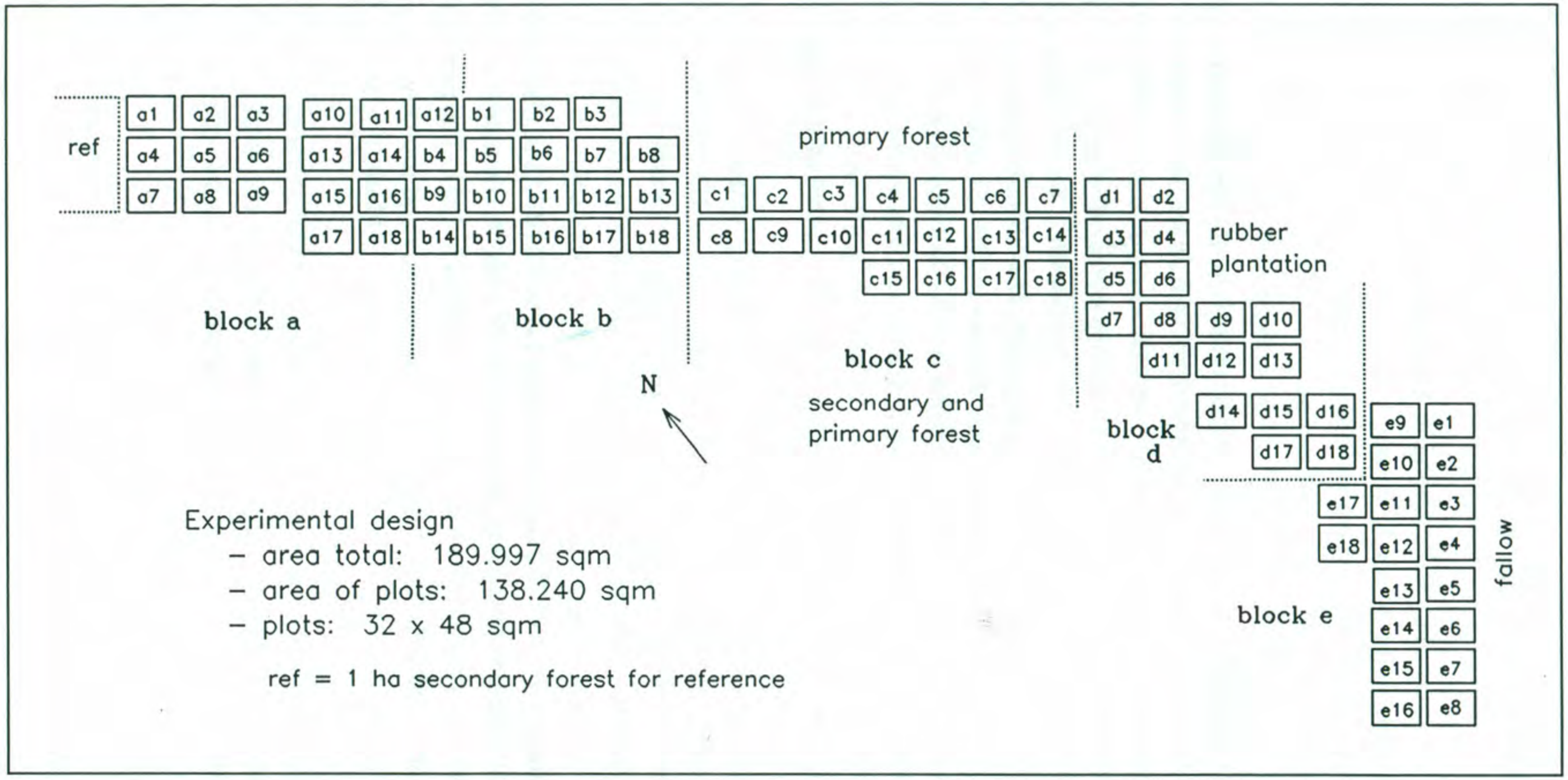

Fig. 2:
Blocks, plots and adjacent sites of the experimental area

Meteorological observations at the EMBRAPA-site near Manaus-AM in 1993, compared to the average of 1971-1993

Osvaldo M.R. Cabral & Carlos Doza

Zusammenfassung:

Meteorologische Beobachtungen auf dem EMBRAPA-Gelände bei Manaus-AM im Jahr 1993 im Vergleich zu langfristigen Mittelwerten der Jahre 1971-1993
Mit Hilfe der Wetterstation der EMBRAPA, die sich etwa 2 km von der SHIFT-Versuchsfläche entfernt befindet, wurden die folgenden meteorologischen Parameter gemessen: Niederschlag, Lufttemperatur, relative Luftfeuchte, Sonnenscheindauer, Verdunstungskapazität der Luft, Windgeschwindigkeit und Bodentemperaturen in unterschiedlichen Bodentiefen. Mittelwerte dieser Parameter für die Jahre 1971-1993 wurden mit dem Jahr 1993 verglichen. Danach war 1993 ein Jahr mit vglw. gleichmäßig verteilten Regenfällen. Dieses spiegelt sich in den Lufttemperaturen wieder, die leicht niedriger als im Mittel waren. Die relative Feuchte war während der feuchtesten Monate höher als im Mittel der Jahre 1971-93, während der trockenen Jahreszeit dagegen niedriger.

1 Material and methods

The experimental area of the SHIFT-project is located in the EMBRAPA main campus (2° 51' south and 59° 52' West), 28 km north east of Manaus. A weather station was installed approximately 2 km away from the experimental field in 1971. The parameters listed below have been measured three times a day, and the daily and monthly averages and totals were calculated:

1. Precipitation
2. Air tempperature
3. Relative humidity
4. Sunshine hours
5. Evaporating power of the air
6. Wind speed
7. Soil temperature (soil surface and 2cm, 5cm, 10cm, 20cm, 30cm above ground).

2. Results and discussion

2.1 Precipitation

Precipitation is responsable for the pattern of the weather, defining two distinctive seasons (wet and dry periods). The monthly average for 1971-1993 and the 1993 totals of precipitation (see fig. 1) show the wet season (October to April) and the dry season (May to September). The peaks occur in March (Fig. 2), when the daily amounts were recorded up to 85mm, and August respectively. In spite of the large difference recorded between the average and the 1993 totals during the wet season (table 1), they are within the standard errors range (±200mm) of the average, as a consequence of their high temporal variability. The daily distribution of the rainfall (see fig. 2), and the comparison of the precipitation totals for 1993 (= 2962mm) and 1971-1993 (= 2503mm) are indicators of a year showing a well distributed rainfall, allthough the amounts observed during the dry season were slightly lower than the average observed for May and June, which can be verified by an analysis of other weather elements.

2.2 Air temperature

The average monthly air temperature (24-26 °C), as well as the maximum (30-33 °C) and the minima (21-23 °C), are presented in fig. 3. The maximum values reflect the uniform distribution of the rainfall, which was slightly below the average, as the precipitation has a convective origin occurring mainly in the afternoon, but the minimum air temperature is not affected. The differences in the daily amplitudes, and consequently the averages, were more pronounced during the beginning of the 1994 wet season (October-November 1993), due to the increase of rainfall.

2.3 Relative humidity

In 1993 a monthly average of 80-90% relative humidity was observed. The values recorded during the wettest months were higher than the average of 1971-1993, but during the dry season the situation changed, and consequently a lower humidity was measured.

2.4 Sunshine hours

The CPAA climatological station does not own a solar radiation sensor, but a Campbell-Stokes sunshine recorder. Its records indicate the amount of energy which reaches the soil surface. The amount of sunshine hours in 1993 varied from 107 hours in February to 226 hours in August. This reflects clearly the cloud cover present throughout the year. Despite the rainy days, values above the average were recorded in May and June. The reasons can be found in short periods of very high precipitation during daytime.

2.5 Evaporating power of the air

The evaporating power of the air was recorded with an atmometer (Piche), which gives an estimate of the evaporative power of the air. The amounts of "evaporation" observed follow the precipitation totals. They were in a range between 45 and 85mm per month, or 1,5 and 2,8 per day respectively, which underestimate the real evaporation rates in a Terra Firme forest (forests: 3,4mm per day, pastures: 3,5mm per day, after Shuttleworth et al. 1984 and Wright et al. 1992).

2.6 Wind speed

The wind speeds observed in cleared areas are usually lower than those measured above a natural forest, mainly during the night and afternoon hours (Batable et al. 1993). The 1993 wind speed observations were lower than the average, propably because of the effect mentioned in Chapter 2.1, with respect to the maximum air temperature.

2.7 Soil temperatures

The average soil temperature for 1971-1993 is not available yet. Therefore a comparision to 1993 is not possible. The temperatures at the soil surface were between 26,7 and 32 °C, decreasing as a function of depth. The values at a depth of 30cm are higher than those recorded at a depth of 20cm, which is not a normal pattern to observe. An explanation might be the distribution of rainfall in 1993. Approximately 73 % of the days were rainy days, as discussed in Chapter 2.1.

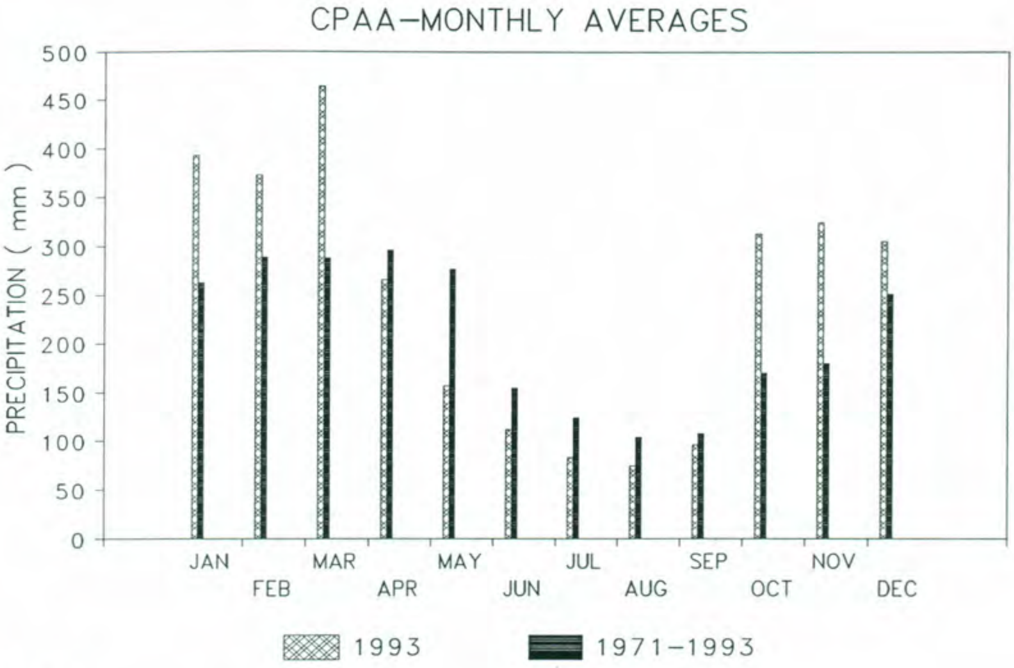

Fig. 1:
Monthly average of precipitation in 1993, compared to the long term averages (1971-1993)

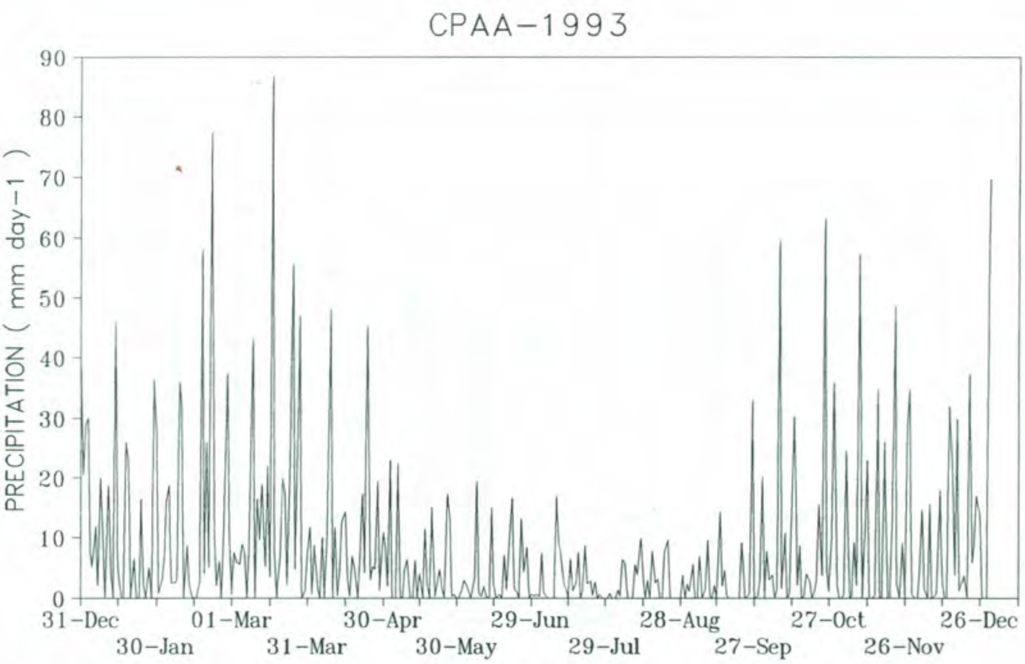

Fig. 2:
Precipitation events in 1993

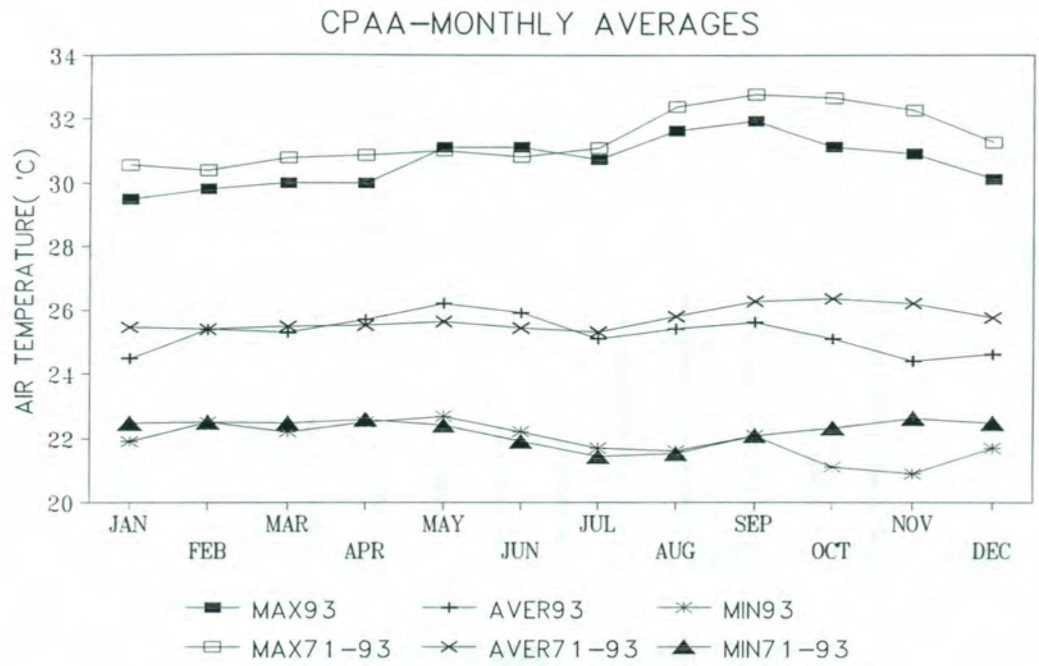

Fig. 3:
Average, minimum and maximum of air temperature in 1993, compared to the long term averages

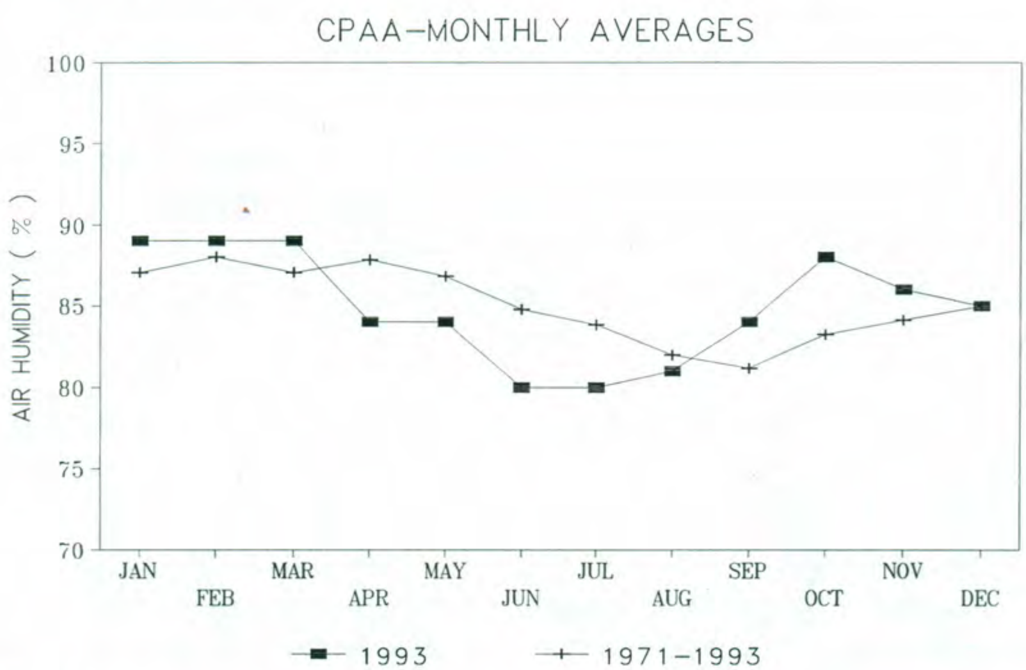

Fig. 4:
Average air humidity in 1993, compared to the long term average humidities (1971-1993)

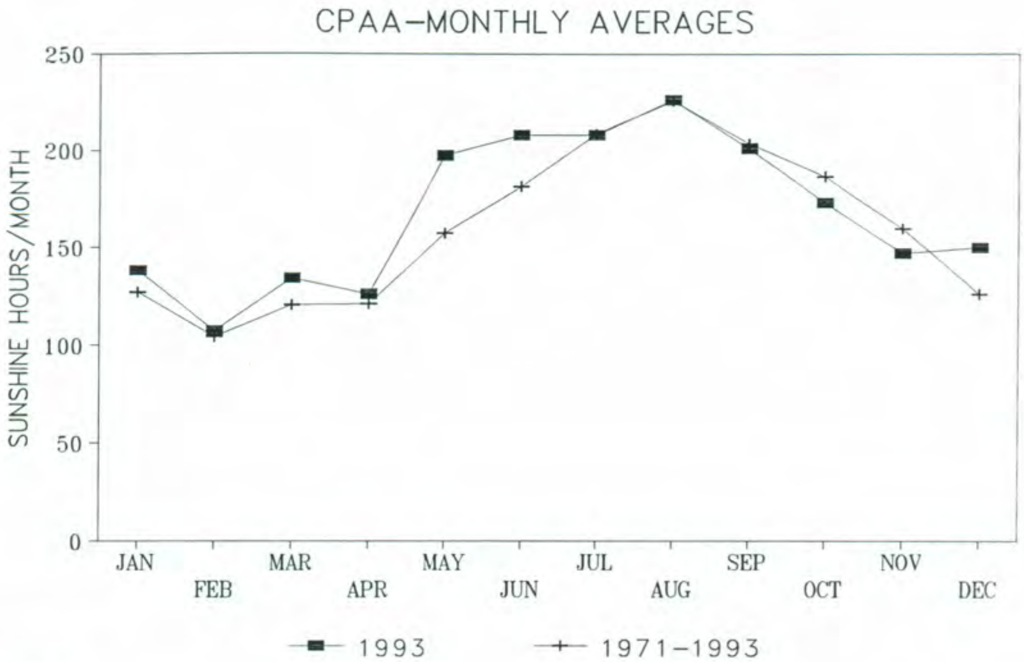

Fig. 5:
Averages of monthly sunshine hours in 1993, compared to the long term average (1971-1993)

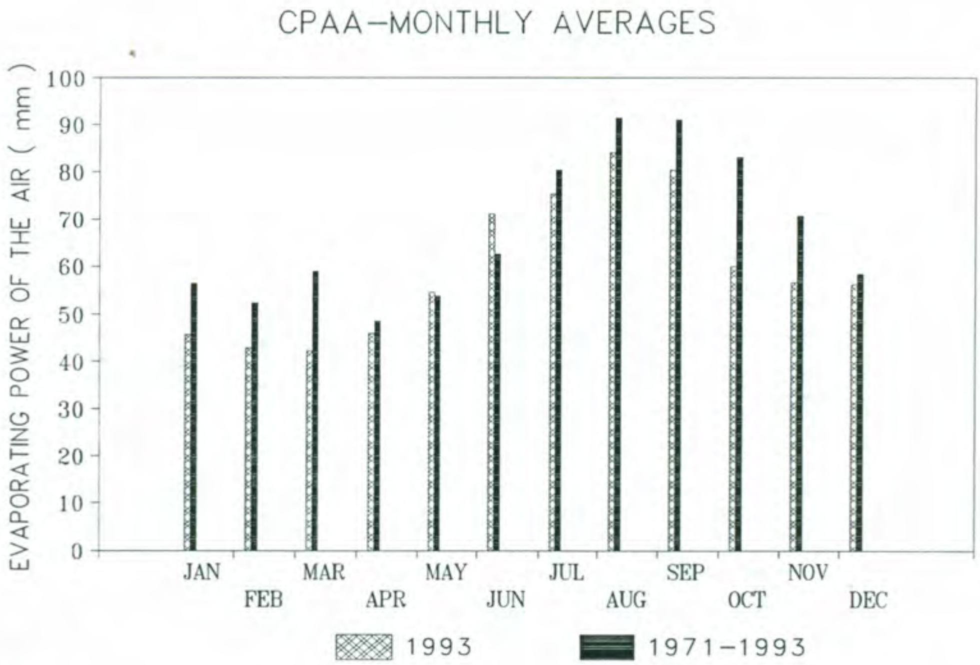

Fig. 6:
Monthly averages of evaporating power of the air in 1993, compared to the long term average (1971-1993)

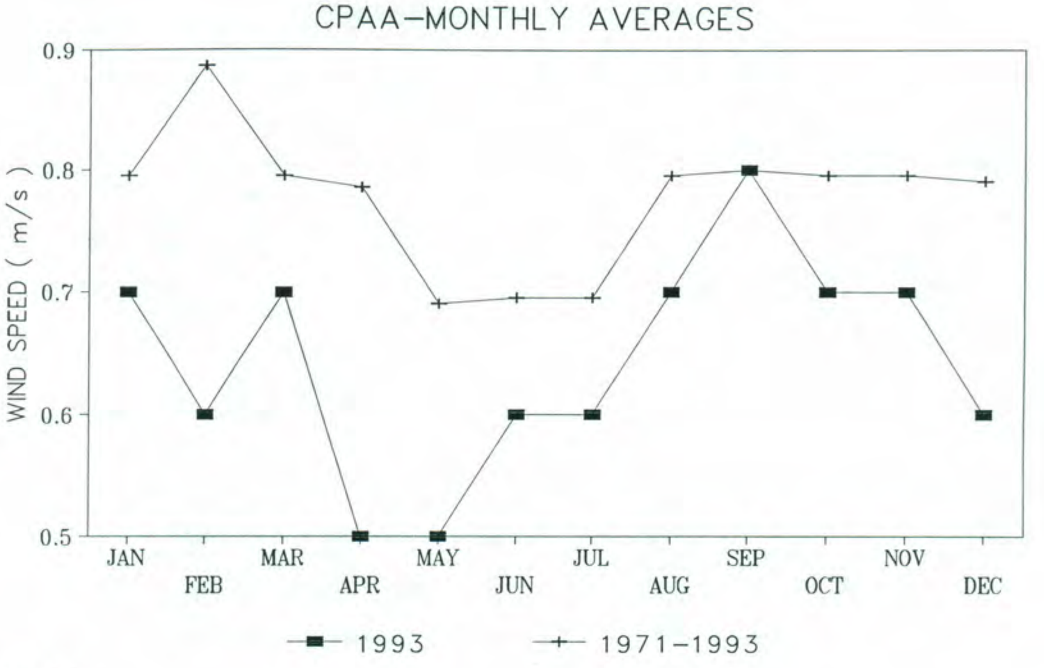

Fig. 7:
Averages of wind speeds in 1993, compared to the long term averages (1971-1993)

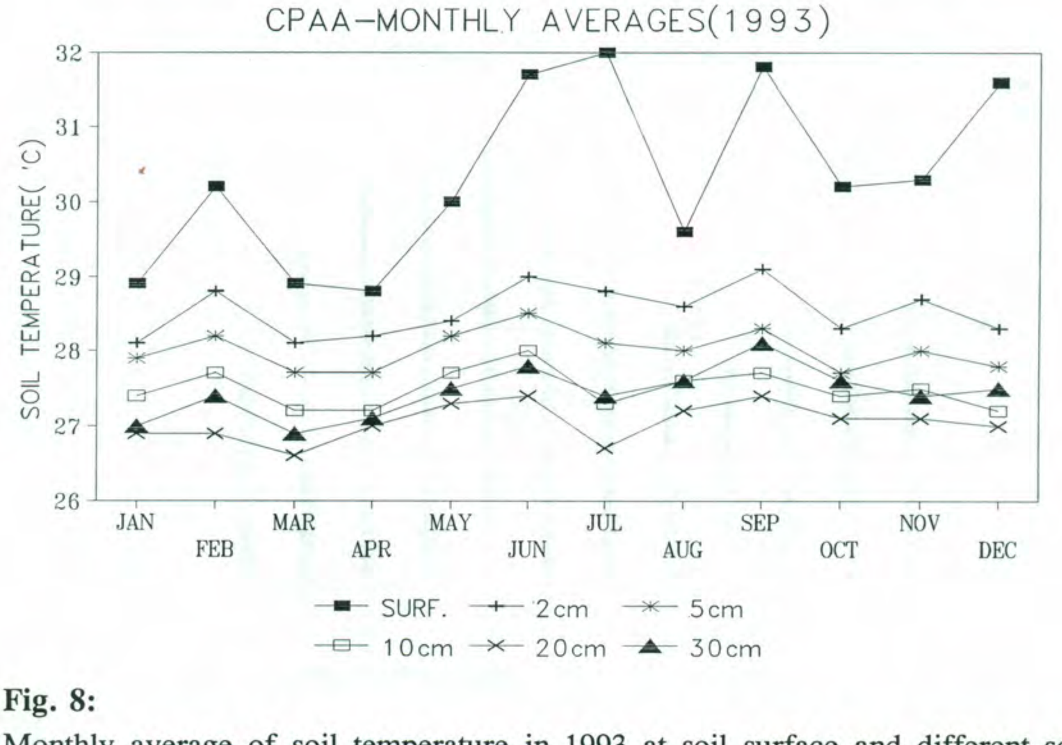

Fig. 8:
Monthly average of soil temperature in 1993 at soil surface and different soil depths

3 References

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Geographische, topographische und bodenkundliche Standortfaktoren und -gradienten der SHIFT-Experimentalfläche

Adauto M. Tavares, Helmut Preisinger & Gilvan C. Martins

Resumo:

Fatores geográficos, topográficos e edáficos e gradientes existentes na área experimental do projeto SHIFT

Uma avaliação da área experimental de 19 ha, através de métodos usualmente aplicados para experimentos agrícolas, em condições de campo, seria difícil devido às diferenças de ambiente e gradientes entre parcelas e blocos. Portanto, para avaliação final, é necessário considerar técnicas (multivariadas) que são comuns em ecologia. O estudo preliminar objetivou detectar supostos gradientes e correlações entre as inclinações das 90 parcelas e alguns parâmetros do solo (pH, Ca, Mg, P, Al e matéria orgânica). Além disso, foram detectados gradientes espaciais dos parâmetros do solo, sob consideração. Uma pré-condição para essas análises, foi um levantament planialtimétrico da área experimental, complementada com fotografias aéreas, as quais serão analisadas posteriormente. Os resultados da presente avaliação mostram baixas ou nenhuma correlações entre os fatores do solo e a inclinação das parcelas, mas distintos gradientes espaciais de Ca, Mg, Al e P na área experimental. Os últimos resultados são discutidos como uma consequência do uso agrícola inicial dos sítios, devido aos diferentes períodos e intensidades de uso.

Summary:

Geographic, topographic and edaphic site factors and gradients in the SHIFT experimental area

An evaluation of the 19 ha experimental area (made up of five blocks) by methods usually applied to agricultural field experiments would be difficult because of environmental differences and gradients between plots and blocks. For a final evaluation, it is therefore necessary to consider (multivariate) techniques which are common in community ecology. This first, preliminary study aims to detect supposed gradients, correlations between the slopes of the 90 plots and some soil parameters (pH, Ca, Mg, P, Al, organic material). Moreover, spatial gradients of the soil parameters under consideration were detected. A precondition for these analyses was a topographic survey of the experimental area. The latter was complemented by aerial photos which *will be analysed later. The results of the present evaluation show no or weak correlations between soil factors and plot slopes, but clear spatial gradients of Ca, Mg, Al and P in the test area. The latter results are discussed as a consequence of former agricultural use of the sites, due to differing periods and intensities of use.*

1 Problemstellung

Bei landwirtschaftlichen Feldversuchen strebt man für alle Parzellen gleiche Standortbedingungen an, um die Wirkungen von Behandlungen bzw. Versuchsvarianten (unterschiedliche Düngung, Bodenbearbeitung u.a.) möglichst isoliert studieren zu können. Die Effekte von Standortunterschieden zwischen Parzellen gleicher Behandlung (Wiederholungen) müssen also klein sein gegenüber der Wirkung der Behandlung auf die Pflanzen, wenn eine Wirkung nachweisbar sein soll. Im Gegensatz dazu hat man es bei synökologischen Untersuchungen, z.B. in der Vegetationskunde, mit vorgegebenen Standortfaktoren und -unterschieden zu tun, die bei Untersuchungsbeginn weder genau bekannt, noch wählbar oder beeinflußbar sind. Soll die Wirkung eines bestimmten Ökofaktors ermittelt werden ("natürlicher" Standortfaktor oder "Behandlung" in einem Versuch), so muß seine Wirkung von der der anderen unterscheidbar sein.

Feldversuche und synökologische Freilanduntersuchungen (oder -versuche) haben also unterschiedliche Grundziele, und ihre statistische Auswertung muß deshalb grundsätzlich verschieden sein:

- Grundfrage von Feldversuchen: Welche Wirkung(en) haben geplante, definierte Manipulationen des Standortes auf Nutzpflanzen? Die Auswertung von Feldversuchen erfolgt vorwiegend durch die Varianzanalyse, aber auch durch Regressions- und Korrelationsanalyse (s. Schuster & Lochow 1979). Multifaktorielle Analysemethoden kommen meist nur dann zum Einsatz, *wenn der Versuch mehrfaktoriell angelegt wurde*.
- Grundfrage bei synökologischen Freilanduntersuchungen: Welches sind die wichtigsten Standortfaktoren, durch die sich die Muster von Pflanzen- oder Tierpopulationen erklären lassen? Bei synökologischen Freilanduntersuchungen kommen von vornherein nur multivariate Analyseverfahren in Frage, weil immer die Artenkombinationen von Standorten mit bestimmten (gemessenen, geschätzten oder beobachteten, kardinal, ordinal oder nominal skalierten) Umweltvariablen korrelliert werden müssen (s. hierzu z.B. Greig-Smith 1979 und Jongman, Ter Braak & Van Tongeren 1987).

Eine Auswertung des 19 ha-Experiments nach den Methoden der Feldversuche ist nicht ohne weiteres möglich, da zwischen den einzelnen Parzellen und Blöcken Standortunterschiede bestehen, die evtl. eine erheblich größere Wirkung auf die Entwicklung der Nutzpflanzen nehmen als die unterschiedlichen Behandlungen[1]. Es war und ist deshalb erforderlich, vorab zu prüfen, ob und welche Standort-Gradienten auf der Experimentalfläche existieren und welche Wirkung sie auf die Muster der *spontanen Vegetation* haben. Dabei wird von der Annahme ausgegangen, daß die Nutzpflanzen ähnlich auf diese Standortunterschiede reagieren wie die Wildpflanzen. Geographische, topographische und bodenkundliche Standortfaktoren-Komplexe[2] sowie solche der Vor-Nutzung werden dabei für wesentlich erachtet und deshalb erfaßt. Nachfolgend werden die geographische Lage der Untersuchungsfläche sowie Gradienten der Topographie und des Bodens dargestellt und diskutiert. Die Arbeiten zur (multivariaten) Korrelation dieser Faktoren mit der spontanen Vegetation sind noch nicht abgeschlossen. Erste Ergebnisse hierzu werden bei Preisinger, Coelho & Siqueira (in Vorber.) dargestellt.

Die vorgelegte Analyse kann als eine vorbereitende Arbeit für die detaillierten bodenkundlichen Untersuchungen, die Mitte des Jahres 1994 beginnen sollen, betrachtet werden.

2 Methoden

2.1 Vermessung der Untersuchungsfläche

Die Vermessung erfolgte mit einem Theodolithen Pentax TH-20D[3]. Es wurden die Flächengröße und Form vermessen (Planimetrie) und in einer Karte (M 1:1.000) dargestellt, die Geländeform vermessen (Nivellement) und die Versuchsfläche in 90 Parzellen von je 48 x 32 m^2 eingeteilt. Da eingemessene Höhenpunkte in der Region fehlen, wurde der vordere linke Eckpunkt der Parzelle e8 als 50 m über dem Meeresspiegel festgelegt. Alle anderen Höhenangaben der Karte beziehen sich auf diesen Meßpunkt. Aus den Höhenpunkten in dem Raster der Versuchsparzellen wurden

---

[1] Überlegungen zur Flächenauswahl zu Beginn des Projekts s. Jahresbericht 1992.

[2] Standortfaktoren-Komplexe i.S. von Billings (1952) und v.Weihe (unveröff.); s. hierzu Preisinger (1991, S. 23ff).

[3] Trotz der größeren Meßgenauigkeit des geometrischen Nivellements (s. z.B. Gelhaus & Kolouch 1991) wurde hier aus Gründen einer schnellen Fertigstellung der Vermessungsarbeiten der trigonometrischen Höhenübertragung der Vorzug gegeben, da die erzielbare Meßgenauigkeit des letztgenannten Verfahrens für den Zweck vollständig ausreichend ist.

Höhenlinien mit 25 cm Höhenäquidistanz interpoliert und diese in eine Höhenlinien-Karte (M 1:1.000) eingezeichnet. Den Höhenlinien wurde das Raster der Versuchsparzellen überlagert.

Das Versuchsgelände der EMBRAPA ist nicht genau vermessen. Eine topographische Karte gibt es lediglich im Maßstab 1:50.000[4]. Für Dokumentationszwecke wurden im Mai 1993 Luftaufnahmen des EMBRAPA-Geländes, einschließlich der Experimentalfläche, angefertigt. Die Aufnahmen wurden mit folgendem technischen Gerät angefertigt:

- Überflug mit einer Cesna des Aeroclube de Manaus, seitlich offen; Fluggeschwindigkeit: 300km/h, Flughöhen: 500m und 900m;
- Kleinbildkamera Canon F1, Objektive f=28 und f=50mm, Aufnahmen freihändig;
- Kamera-Neigung: bis zu 90°.

Mit Hilfe der Luftaufnahmen soll u.a. eine Übersichtskarte des EMBRAPA-Geländes im Maßstab 1:5.000 angefertigt werden. Der Überflug wird zum Ende des Projekts wiederholt, um Veränderungen der Versuchsfläche und des Wegesystems (z.B. Erosionsschäden) zu dokumentieren.

2.2 Bodenprobennahme

Bis jetzt wurden zu drei Zeitpunkten Bodenproben entnommen (vgl. Jahresbericht 1993):

1. vor dem Roden und Brennen der Fläche im August 1992 (nur Teilflächen, rasterförmige Probennahme aufgrund der dichten Sekundärvegetation nicht möglich),
2. direkt nach dem Roden und Brennen (annähernd rasterförmig),
3. Vier Monate nach dem Roden und Brennen und nach Vermessung und Parzellierung der Fläche.

Die 3. Probennahme, die erstmalig eine exakte rasterförmige Bodenprobennahme und damit die Ermittlung evtl. vorhandener Gradienten von Bodenkennwerten gestattete, wurde folgendermaßen durchgeführt:

---

[4] Ministério do Exército, Dep. de Engenharia e Communicaçoes, Diretorio de Serviço Geográfico Região Norte do Brasil, folha SA.21-Y-A-IV-3 (Efigênio de Sales)

1. Entnahme von ca. 3 dm^3 Boden mit der Pflanzschaufel aus den oberen 15cm (Probennahme einschließlich Ah und organischer Auflage, soweit vorhanden, dabei Entnahme von jeweils einer Bodenprobe aus der Mitte der Parzellen (=90 Proben);
2. Probennahmen mit dem Edelmann-Bohrer aus Bodentiefen von 0-100 cm aus der Mitte von je einer Parzelle der Blöcke a, b, c, d und e. Die Proben wurden in Tiefenstufen von 10 cm getrennt analysiert.
3. 6 Bodenproben wie unter (1) aus der 1 ha-Referenzfläche (Sekundärwald).

Die folgenden Analysen konnten bisher im Bodenkundelabor des CPAA durchgeführt werden: pH, Ca, Mg, Al, P und organische Substanz. Nachfolgend werden nur die Bodenproben der 3. Bodenprobennahme aus der Mitte der Parzellen und aus 0-15 cm Tiefe ausgewertet (Mittel- und Extremwerte s. *Bueno*).

2.3 Statistische Analysen

Die Analyse der räumlichen Gradienten der Elementgehalte auf der Experimentalfläche wurde in folgender Weise durchgeführt:

Für die Erfassung räumlicher Standortgradienten wurden, ausgehend von Parzelle a1, allen 90 Parzellen Koordinaten zugewiesen, und zwar in der Längsausdehnung der Fläche (Block a-e) von 1-24 und in der Breitenausdehnung (N-S) von 1-15 (Koordinaten 1/1 für Parzelle a1 bis 24/15 für Parzelle e8). Diese Koordinaten wurden (univariat) mit den Bodenfaktoren korreliert.

Für die Erfassung mittlerer Flächenneigungen wurden für alle Parzellen die Neigungswinkel errechnet. Diese ergeben sich aus der maximalen Differenz der Höhen der Eckpunkte der Parzellen dh und dem Abstand dieser Eckpunkte x als $\tan \alpha = dh/x$. Dabei wird vereinfachend davon ausgegangen, daß die Parzellen schiefe Ebenen darstellen.

Zur Untersuchung von Korrelationen zwischen den Elementgehalten Ca, Mg, Al, P sowie pH und dem Anteil der organischen Substanz im Boden und den genannten geographischen und topographischen Parametern wurde der Spearman-Rank-Korrelations-Test herangezogen (Programm SIGMA-STAT®). Eine multivariate Analyse dieser Faktoren im Hinblick auf die spontane Vegetation (CANOCO, Ter Braak 1981) erfolgt bei Preisinger, Coelho & Siqueira (in Vorber.).

3 Ergebnisse und Diskussion

3.1 Geographische Lage der Experimentalfläche und Topographie (Höhenlinien-Karte[5])

Die Untersuchungsfläche liegt 28 km nordöstlich von Manaus in 2° 51' südlicher Breite und 59° 52' westlicher Länge. Die Fläche befindet sich auf einem Höhenrücken, ist langgestreckt und hat eine maximale Längenausdehnung von 1412 m in Richtung WNW. An ihrer breitesten Stelle mißt sie 200 m und an ihrer schmalsten Stelle 75 m (weitere allgemeine Angaben zur Experimentalfläche s. Jahresbericht 1992).

Die Topographie der Untersuchungsfläche weist die folgenden Merkmale auf: Der höchste Ort befindet sich im Block e, im Schnittpunkt der Parzellen e5, e6, e13 und e14 (h=50,3m), der niedrigste im linken vorderen Eckpunkt der Parzelle d17 (h=40,0m). Die Untersuchungsfläche hat also einen maximalen Höhenunterschied von 10m. Zwischen den Parzellen d3 und d4 befindet sich eine Senke, so daß diese Parzellen einen Neigungswinkel von 4,4° bzw. 5,6° aufweisen. Zur Südwestseite der Blöcke a bis c fällt das Gelände um bis zu ca. 4m ab. Nur ca. 23 % der Parzellen kann man als annähernd eben ansehen (Höhendifferenz in der Parzelle < 0,5m). Aus der Übersicht (Abb. 1) geht hervor, daß Block a den höchsten Anteil "ebener" Parzellen aufweist. Am südwestlichen Rand der Blöcke a-c fällt das Gelände ab. Die Parzellen der Blöcke d und e weisen überwiegend Flächenneigungen über 1° auf.

3.2 Bodenfaktoren und Topographie: räumliche Gradienten und ihre Bedeutung für die spätere Interpretation des Blockexperiments

Es wird vermutet, daß die unterschiedlichen Neigungswinkel der Parzellen eine Reihe von Standortfaktoren des Bodens beeinflussen, die für die Fläche als Pflanzenstandort von Bedeutung sind. Deshalb wurden die Rang-Korrelationen zwischen dem mittleren Neigungswinkel der Parzellen und den z.Z. zur Verfügung stehenden Bodenkennwerten pH, Ca, Mg, Al, P und organische Substanz des Bodens geprüft (bisher gemessene Bodenkennwerte s. *Bueno*). Die Ergebnisse des Tests ergeben keine oder sehr schwache Korrelationen zwischen diesen Faktoren (Tab. 1, Spalte Neig). Es stellen sich zwei Fragen: 1. welche anderen, hier (noch) nicht untersuchten Bodenfaktoren, die von den bereits untersuchten unabhängig sind, werden durch die Flächenneigung beeinflußt?

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[5] Auf die Wiedergabe der großformatigen Höhenlinienkarte muß hier verzichtet werden.

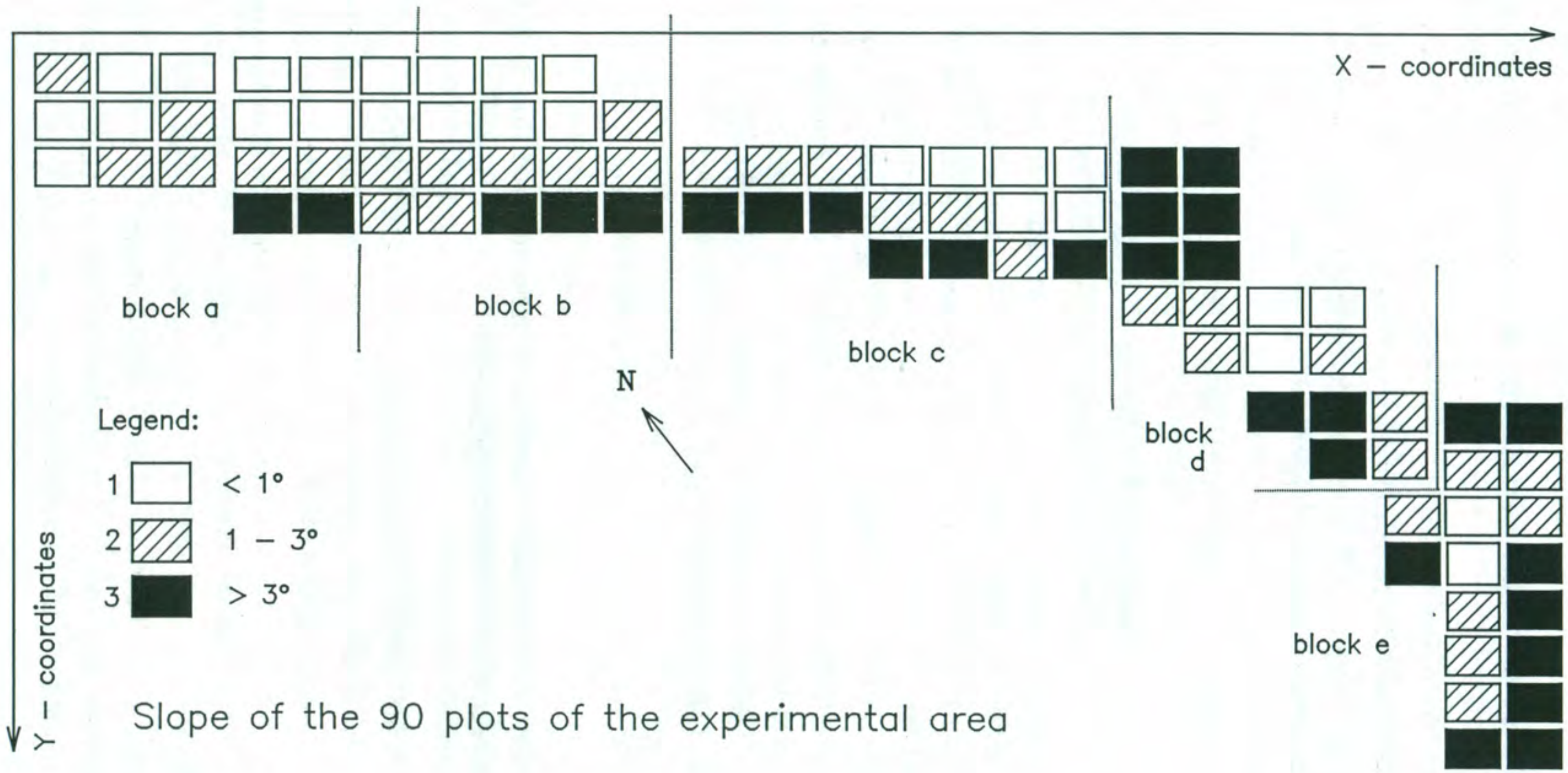

Abb. 1:
Schematische Darstellung der Experimentalfläche und mittlere Flächenneigung der Parzellen (Abmessung: 48 x 32 m); Richtungen der analysierten Gradienten X und Y (s. weiter unten im Text)

Tab. 1:
Korrelationen zwischen den gemessenen Bodenfaktoren pH, Ca, Mg, Al, P und organische Substanz (Org) sowie den topographischen und geographischen Parametern "maximale Neigung der Parzellen" (Spalte Neig), "Gradient in X-Richtung" (Spalte X)[1] und "Gradient in Y-Richtung" (Spalte Y)[1], gerechnet nach dem Spearman-Rank-Order-Korrelations-Test. Bei p-Werten < 0,05 wird davon ausgegangen, daß die beiden jeweiligen Faktoren miteinander korreliert sind (-- = keine Korrelation), Fettdruck: Korrelationskoeffizienten >0,5.

	Ca	Mg	Al	P	Org	Neig	X[1]	Y[1]
pH	**0,52**	0,48	**-0,67**	--	--	--	0,26	--
Ca	------	**0,86**	**-0,56**	-0,23	**0,55**	0,21	**0,55**	0,47
Mg		------	-0,50	--	--	--	0,47	0,42
Al			------	0,48	0,35	-0,27	-0,50	-0,47
P				------	0,35	-0,31	**-0,57**	**-0,57**
Org					------	--	--	--

[1] Zur Richtung der X/Y-Koordinaten s. Abb. 1

2. war die Art der Bodenprobennahme ungeeignet, um eventuelle Unterschiede zu erfassen? Die erste Frage kann derzeit nicht beantwortet werden. Die zweite Frage ist zu bejahen, weil sich Veränderungen durch die Hangneigung bei dem z.T. stark kompaktierten, lehmig-tonigen Latosol vorwiegend an der Bodenoberfläche abspielen werden, die Proben aber aus einer Tiefe von 0-15 cm gezogen wurden. Ein weiterer Grund für fehlende Korrelationen könnte das sehr grobe Probennahme-Raster sein (1 Probe aus der Mitte jeder Parzelle), wenn es starke Schwankungen von Bodenqualitäten im cm- oder dm-Maßstab gibt, was derzeit nicht bekannt ist.

Demgegenüber läßt sich ein deutlicher Standortgradient entlang der Flächenausdehnung nachweisen (Tab. 1, Spalten X und Y): Von Block a nach Block e steigen der Ca- und Mg-Gehalt im Boden an und P- und Al-Gehalt nehmen ab. *Dieses könnte eine Folge von Veränderungen des Boden durch die landwirtschaftliche Nutzung der Standorte sein.* Die Nutzung der Flächen schritt von Südwesten nach Nordosten voran. Ob die Standorte der Blöcke d und e auch intensiver genutzt wurden als die übrigen, ist bisher nicht bekannt.

Die hier festgestellten Zusammenhänge spiegeln sich auch in Wuchsformen- und Artenzusammensetzungen der spontanen Vegetation wider (vgl. *Preisinger, Siqueira & Coelho*). Außerdem deutet sich schon jetzt an, daß auch Nutzpflanzen auf die ermittelten Standortgradienten reagieren, und zwar *trotz* der lokalen (Grund-)Düngergaben ins Pflanzloch bzw. auf die Bodenoberfläche um den Stamm. *Moraes* stellt abnehmende Wuchshöhen der jungen Kauschukbäume von Block a nach Block e fest, d.h. mit zunehmenden Ca-Gehalten und abnehmenden P- und Al-Gehalten[6].

Es könnte sein, daß sich die festgestellten Gradienten im Laufe der Versuchsdauer durch Überlagerung mit der rezenten Nutzung nivellieren. Trotzdem muß zum Ende des Versuchs überprüft werden, ob etwaige Standortgradienten und -unterschiede die Auswertung des Blockversuchs stören.

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6 "zunehmend" bzw. "abnehmend" heißt hier: Trends im Rahmen der ermittelten Korrelationskoeffizienten zwischen ± 0,5 und 0,6.

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Analysis of growth form types and floristic composition due to past disturbance and plantation management in the SHIFT experimental area[1]

Helmut Preisinger, M. do Socorro G. Siqueira & Luiz F. Coelho

Resumo:

Análise dos tipos das formas de crescimento e da composição florística, devido ao distúrbio anterior e o manejo do plantio na area experimental do projeto SHIFT
Em Terra Firme próximo a Manaus, Amazonas, está sendo executado um experimento com sistemas de policultivo de plantas úteis, estabelecido em um plantio de seringueira abandonado. São testadas diferentes combinações de plantas úteis em 90 parcelas e 5 blocos. Isso leva inevitavelmente a um manejo diferente da vegetação espontânea, possibilitando estudar seu impacto sobre as plantas úteis. Se por um lado, a vegetação expontânea pode competir com as culturas (luz, nutrientes, espaços etc.) e nesse caso, devem ser eliminadas, por outro lado pode, ser importante para armazenar nutrientes. Se esses processos opostos podem ser otimizados em favor das culturas, através do controle apropriado da vegetação sílveste, é uma questão que deve ser examinada. Quatro meses após a limpeza e seis meses após o plantio das culturas no campo, foram efetuadas análises da vegetação com o objetivo de descrever as estruturas das formas de crescimento e a composição florística. Os resultados mostram modelos de vegetação que dependem principalmente do uso anterior dos locais, mas há diferenças que podem ter sido causadas pelo manejo recente das parcelas. Muitas das mais de 300 espécies presentes na área experimental mostram uma reação específica ao distúrbio. O termo "distúrbio" é usado de acordo com Grime (1979). A vegetação sob estudo está ajustada ao conceito das estratégias de Grime. Uma classificação das espécies comuns, devido a teoria CSR, é portanto, possível e pode ser útil para a compreensão dos modelos de vegetação.

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[1] Work presented as a poster on the symposium "Tropical Useful Plants: Biology - Ecology - Economy" held in Hamburg, Germany, September 22 - 24, 1993.

Zusammenfassung:

Analyse von Wuchsformentypen und der floristischen Zusammensetzung unter dem Einfluß der Störung des Wildpflanzenwuches durch das Plantagen-Management auf der SHIFT-Versuchsfläche

Auf einem Terra Firme-Standort bei Manaus wird in einem 19 ha großen Feldversuch eine aufgelassene Kautschukplantage durch eine Mischkultur-Plantage rekultiviert. Dabei werden in 90 Parzellen und 5 Blöcken (Wiederholungen) verschiedene Nutzpflanzen-Kombinationen erprobt. Dieses führt zwangsläufig zu einem unterschiedlichen Management der spontanen Vegetation und der Möglichkeit, deren Wirkung auf die Nutzpflanzen zu untersuchen. Einerseits ist die Wildvegetation eine Konkurrenz, andererseits ein wichtiger Nährstoffspeicher für die Nutzpflanzen. Ob diese beiden entgegengesetzten Forderungen zugunsten des Wachstums der Nutzpflanzen optimiert werden können, ist ein längerfristiges Ziel der Untersuchungen. Vier Monate nach Flächenrodung und sechs Monate nach den Pflanzungsarbeiten wurden Vegetationsuntersuchungen durchgeführt, die die Wuchsformen-Struktur und die floristische Zusammensetzung zum Ziel hatten. Die Ergebnisse zeigen Vegetationsmuster, welche vorwiegend durch Unterschiede in der Vornutzung geprägt sind, jedoch lassen sich bereits Unterschiede durch das aktuelle Management der Parzellen erkennen. Viele der über 300 Pflanzenarten, die auf der Untersuchungsfläche vorkommen, zeigen eine charakteristische Reaktion auf Störung ("disturbance" im Sinne Grime's 1979). Die untersuchte Vegetation scheint innerhalb des Gültigkeitsbereiches von Grime's Strategiekonzept zu liegen. Eine Klassifizierung häufig vorkommender Pflanzenarten nach der CSR-Theorie wird für möglich und sinnvoll angesehen.

1 Basic ideas, assumptions and problems

On a *terra firme*[2] site near Manaus, Amazonas, an experiment in recultivating a fallow rubber plantation by establishing mixed plantations of selected useful plants is carried out. Different crop combinations and types of management (plantation systems) are to be tested in order to find a way for sustainable use of these unfertile sites (for a general overview on the design of the experiment see Lieberei et al. 1993 and *Lieberei et al.*). The spontaneous vegetation in the different plantation systems evolve in a different way, due to plot management.

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[2] terra firme: firm or solid land, in contrary to inundated land of the river Amazon.

The field trial on a total area of 19 ha comprising 5 blocks with 18 plots each has been laid out on the crest of a hill. The area is elongated and undulating. When the land was cleared, only the above-ground parts of the spontaneous vegetation were destroyed. The roots and rhizomes remained in the soil, so that the previous vegetation pattern survived in latent form. The soil is yellow latosol throughout. There are differences in the soil characteristics, which appear to be mainly due to the different historical uses of the sites (see *Tavares, Preisinger & Martins*). These are not the ideal conditions for a field trial. Consequently, in order to analyse the plantation systems, plots and blocks and the overall system, it is necessary to have as much information as possible about the initial conditions and to analyse existing ecological gradients, site differences and their spatial patterns. Recording and subsequent comparitive analysis of these different types of vegetation are therefore of special interest for at least three reasons:

1. to improve the understanding of the mechanisms of competition[3] for light, space and nutrients between the useful plants and wild plants: On the one hand, the spontaneous vegetation can constitute competition for the crops, in which case it must be suppressed. On the other hand, the spontaneous vegetation can be an important store for nutrients, which become available to the crops after dieback and mineralization of the biomass. Whether these opposed processes can be optimized in favour of the crops by appropriate control of the wild vegetation, is a question that is to be examined.

2. to develop an adequate evaluation strategy of the block experiment (see also *Tavares, Preisinger & Martins*): This requires carrying out a gradient analysis, respectively examining the species composition of different stands, to detect underlying environmental gradients by correlating the vegetation patterns with known environmental factors.

3. To accumulate knowledge of the response of frequently occurring species to different kinds of disturbance (the term "disturbance" is used here in accordance with Grime 1979). This knowledge, is necessary to solve the problems indicated in (1).

A methodology for a vegetation survey on a *floristic* basis, which can represent an area of 19 ha on the basis of a quantitative data set (e.g. cover values of the species) and which can be carried out with one or two workers in a reasonable time is not possible

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[3] The problem is considered here to solve applied problems, but it is a fundamental but controversial problem in vegetation science which is still discussed and has not yet been solved satisfactory (see e.g. Ellenberg 1953, Grime 1979, Austin 1980, Tilman 1988, Austin & Smith 1989)

to achieve (cf. Greig-Smith 1983, p 299 ff). Moreover, after clearing the area in October 1992 there was a need to do this work as soon as possible because the secondary vegetation regenerates rapidly during the wet season. Therefore the vegetation analysis was carried out in two steps:

1. Estimating the cover values of *growth form types* present in the plots. This survey results in a *quantitative data set* on a *structural basis*.

2. Collecting *presence/absence data* of the *floristic composition* of the plots under consideration.

Whether the two different data sets can be combined, giving improved insights into vegetation composition, is a question which will be considered elsewere (Preisinger, Siqueira & Coelho, in preparation).

The present knowledge of the ecological behaviour of common primary and secondary forest species of Amazonian terra firme sites is poor, and ecological knowledge of single species is distributed over a wide range of publications which makes evaluation of this information difficult. Summarizing descriptions of common species of the flora are often unprecise and mostly related to floristical traits (e.g. Prance 1975, da Silva et al. 1977, Wessels Boer et al. 1976), or are on the level of genera (Gentry 1993). Therefore basic knowledge of autecology even of common species can still be accumulated by simple techniques and methodologies (observation, estimation, counting, comparision).

2 Methods

2.1 Analysis of growth form types (quantitative data set)

Life form and growth form types have prooved to be a valuable tool to indicate environmental conditions of vegetation stands in the temperate zones of the world (Raunkiaer 1937, Ellenberg 1979 inter alia). Dansereau (1951) suggests a system of growth form types and their graphical presentation ("Dansereau-Diagrams") which include tropical vegetation types. Especially in situations of disturbance gradients there is no doubt that a significant change in growth form composition takes place (see Preisinger 1991 for an example of riverbank vegetation).

The approach presented here is based on the assumption that the composition of the growth forms present on a site and hence the growth form distribution in the test area is a key indicator of past use and of associated site differences. It is therefore convenient to use the growth-form structure of the spontaneous vegetation for a gradient analysis. Four months after clearing - and after the area had been surveyed and divided into plots - growth form types of the spontaneous vegetation of all 90 plots of the trial were assessed quantitatively, i.e. on the basis of their respective area coverage. To meet practical requirements, the following seven growth form types were distinguished:

1. Trees
2. Shrubs
3. Lianas and herbs, spreading with runners
4. upright growing herbs
5. Stolon grasses
6. Rhizome or tussock grasses
7. Ferns, spreading by rhizomes (*Pteridium aquilinum* predominant).

The plot size (48 x 32 m^2) is taken as the reference area, because this will inevitably also be the most important unit of area in subsequent analyses. The vegetation matrix obtained consists of the seven identified growth forms of the 90 plots with the cover rates for the species of a given growth form.

There is a clear demand for a more sophisticated classification of growth form types for the plant species of the study area, but this must meet the practical requirements of the studies. Therefore an advanced classification system (cf. Box 1981) is not applicable. Above all, the trees must be divided into several sub-types, which could be related to the role of the species in forest succession.

2.2 Analysis of the flora (presence/absence-data set)

The floristic composition of a vegetation stand can be an indicator of the site history, especially for historical use or past disturbance, if there is sufficient autecological information available for the species under consideration. Harper (1982) doubts that ecological variation can be described adequately by taxonomic characters, because taxonomic groupings are based on stable, conservative traits and "it may be just the taxonomically useless characters that are mainly responsible for determining the precise ecologies of organisms". However, different comparitive approaches in classification of the most common species of flora according to their ecological response to site factors (Ellenberg 1979, inter alia) or to eco-morphological traits which are favourable for the plants under certain environments (Grime 1979, Grime, Hodgson & Hunt 1988) were successfully applied to solve practical problems in agriculture, nature conservancy and landscape ecology. Even on higher taxonomical levels there might be superior ecological traits and behaviours (e.g. all *Amaranthaceae* and *Chenopodiaceae* are disturbance tolerant or ruderal herbs).

An intitial floristic study was carried out before the secondary forest in the test area was cleared in October 1992. One year later, after the installation of the mixed plantation, a more detailed floristic study was completed. The flora of 71 of the 90 plots of the experiment were surveyed separately. The monoculture systems were left unattended in the floristic analysis, except for two plots used for comparison. From each plot under consideration a sample of each plant species found was collected and prepared, identified and stored for future comparisons.

3 Results

3.1 Spatial distribution of growth form types

The vegetation pattern in the experimental area four months after clearance represents a moment in vegetation development. The growth form structure of the different plots is composed by those organisms which were able to build up a biomass after clearance by regenerating from

1. subterranean roots and shoots,
2. overground shoots which were not destroyed by the fire,
3. surviving seeds which were present before clearance,
4. anemochorous and zoochorous seeds which reached the area after clearance.

As known so far, a majority of the species belong to groups (1) and (4).

The spatial distributions of the growth form types with the highest cover values (trees, stolon grasses, creeping herbs/lianas, tussock/rhizome grasses) are shown below (Figs. 1-4). The experimental area is represented schematically. The smallest spatial unit considered is the 48 x 32 m^2 plot. Neighbouring vegetation types likely to influence growth form structure, respectively composition of species in the experimental area (by invasion of single species with the aid of seeds, roots, rhizomes or runners) are marked by an ellipse. From Figs. 1-4 the following trends can be seen:

Trees (Fig. 1)
The significance of this growth form diminishes from block a to block e. The main reason may be the longer lasting and more intensive use of the sites belonging to blocks d and e.

Stolon grasses (Fig. 2)
Sites with a high percentage of trees which regenerate poorly or not at all from stool shoots (mainly primary forest species?) are left with bare soil after clearing and burning, and are colonized first by stolon grasses (R-strategists), which are present everywhere by a seed potential.

Creeping herbs and lianas (Fig. 3)
The sowing of *Pueraria phaseoloides* as a cover crop in the former rubber plantation on the present experimental area and in the remaining rubber plantation explains much of the pattern of this growth form, but there are other plant species belonging to this group which are dominant in some places.

Tussock and rhizome grasses (Fig. 4)
These growth forms occur together with bracken (*Pteridium aquilinum*) in block e. The latter is found only here. The dominance of growth forms which propagate vegetatively by means of creeping underground shoots is favoured by frequent hoeing.

The potentiality to find ecological explanations which explain the growth form pattern observed will rise if there was more information about historical use than is available at present.

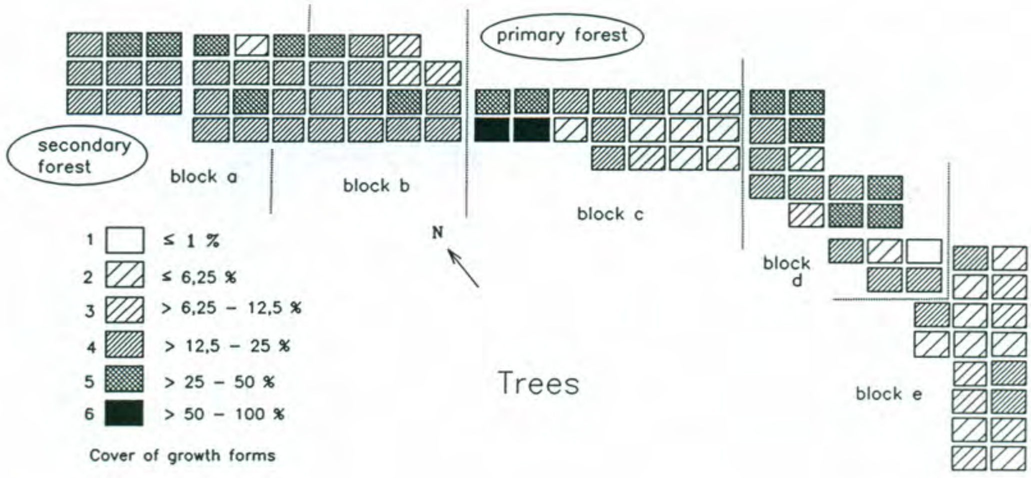

Fig. 1:
Spatial distribution of the growth forms in the experimental area: trees

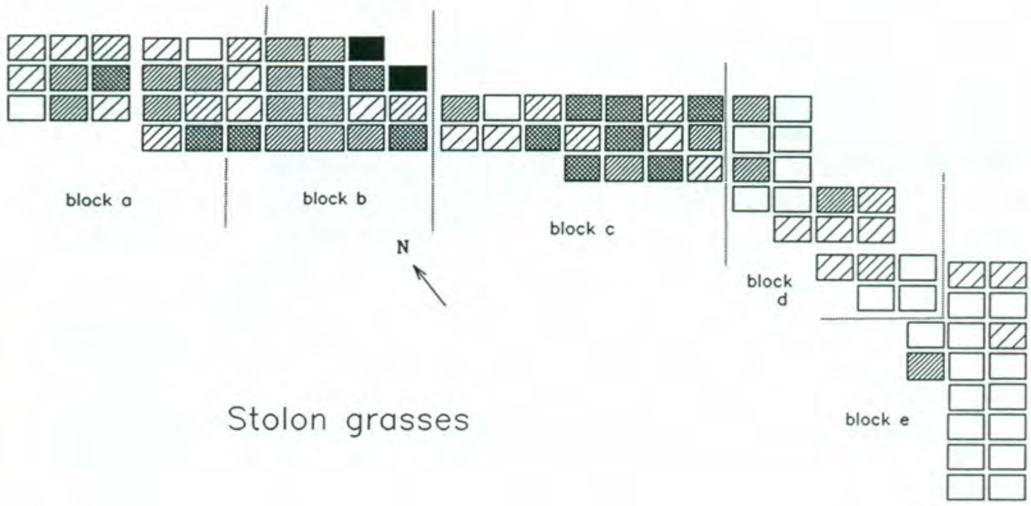

Fig. 2:
Spatial distribution of the growth forms in the experimental area: stolon grasses (legend to cover of growth forms see Fig. 1)

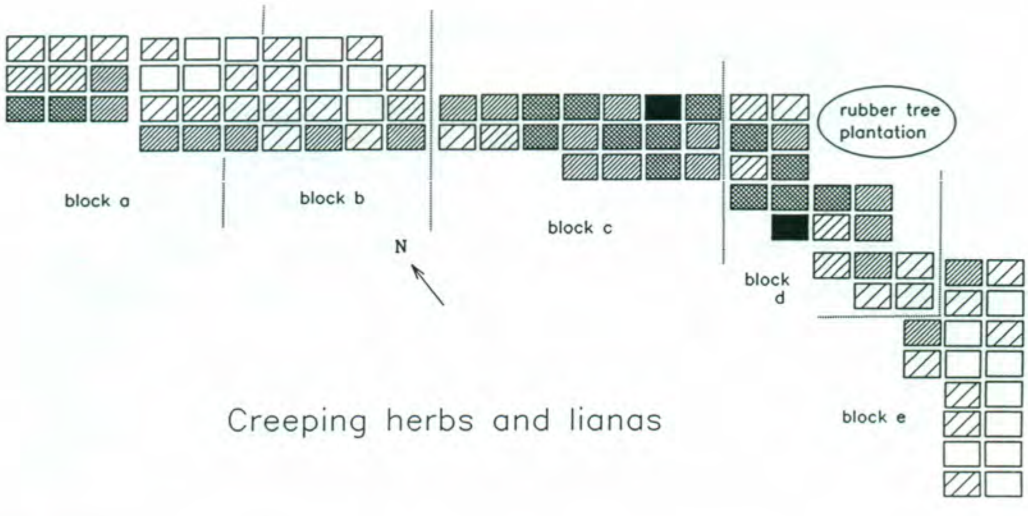

Fig. 3:
Spatial distribution of the growth forms in the experimental area: creeping herbs and lianas (legend to cover of growth forms see Fig. 1)

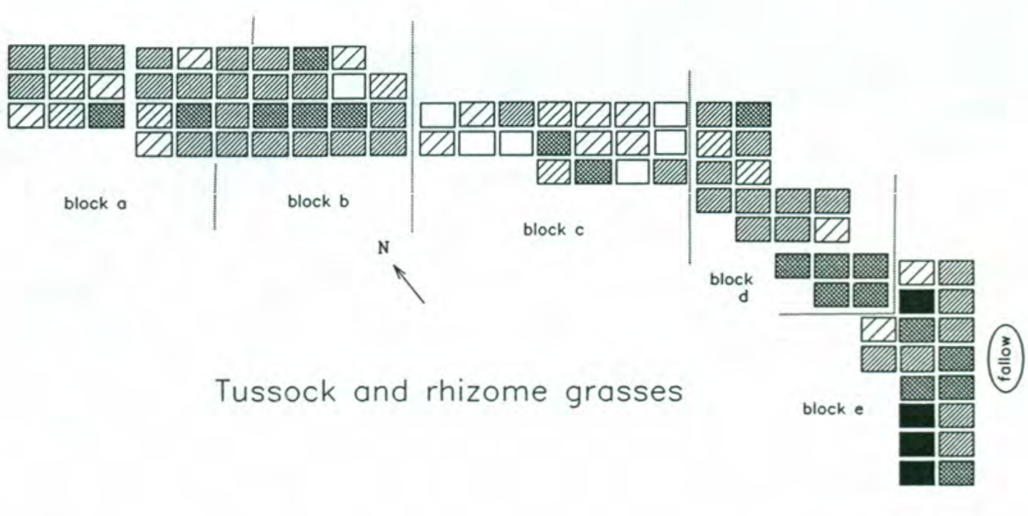

Fig. 4:
Spatial distribution of the growth forms in the experimental area: tussock and rhizome grasses (legend to cover of growth forms see Fig. 1)

3.1 Floristic composition

To get an idea of the variation in Amazonian secondary vegetation (*capoeira*), a comparison of floristic composition between the experimental area near Manaus before clearence and an agricultural area lying fallow in the eastern Amazon (Zona Bragantina), was carried out on the level of the plant families (Table 1).

Table 1:

Comparision of plant families with the most species in the test area (rank 1 to 5) before slashing and burning and at the margins of the primary forest adjacent to the test area (SHIFT project Manaus-AM) and in a test area in the Zona Bragantina, eastern Amazon (SHIFT project Belém, from Denich 1989); number of species in brackets

	Manaus, Amazonas		Igarapé-Açu, Pará
	experimental area	margin of prim. forest	(Denich 1989)
1	Melastomataceae (15)	Moraceae (7)	Myrtaceae (13)
2	Bignoniaceae (10) Moraceae (10) Rubiaceae (10)	Chrysobalanaceae (6)	Mimosaceae (12) Fabaceae (12)
3	Apocynaceae (9) Fabaceae (9)	Melastomataceae (5)	Caesalpiniaceae (10)
4	Mimosaceae (7)	Sapotaceae (4) Caesalpiniaceae (4)	Rubiaceae (8) Sapindaceae (8)
5	Arecaceae (6)	(various families)	Annonaceae (7)

In the secondary forest near Manaus *Melastomataceae*, *Bignoniaceae, Moraceae* and *Rubiaceae* are predominant as to numbers of species, in the test area of the Zona Bragantina *Myrtaceae* and *Leguminosae (Fabaceae, Caesalpiniaceae, Mimosaceae)*. The very different taxonomic (and hence also floristic) composition of the two Amazonian secondary vegetation sites has to be sought partly in their different history (shifting cultivation for about 90 years in Igarapé-Açu, primary forest slashed and burned ten years ago in Manaus). The impact of other environmental factors as different geographic location and differences in soil types is difficult to estimate at present.

A comparision of the 27 plant families with the most species in the spontaneous vegetation in the experimental area, before and one year after the installation of the mixed culture plantion (Fig. 5), reveals a sharp increase of the portion of species of

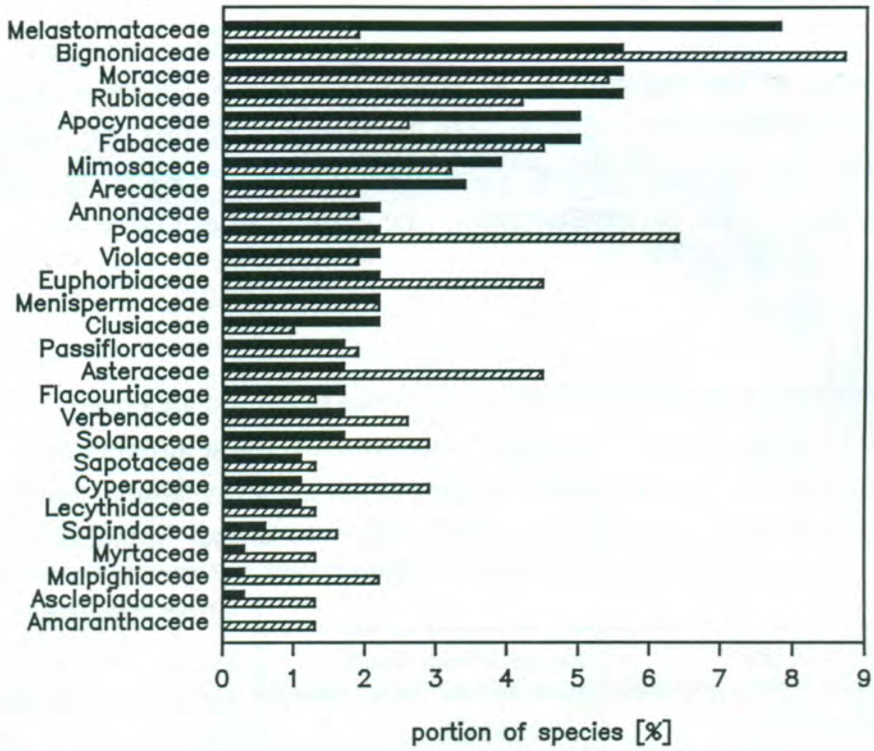

Fig. 5:

Plant families with the most species on the test area before clearance (solid bars), displayed in descending order, compared to those one year after clearance, respectively nine months after planting (hatched bars)

only herbaceous families (*Poaceae, Cyperaceae, Amaranthaceae*) and herbaceous repre-sentitives of other families (*Asteraceae, Solanaceae, Euphorbiaceae, Asclepiadaceae*). These species are "invaders" or "ruderals" in a wide sense or, expressed in terms of CSR-theory (Grime 1979), behave as ruderals (R), competitive ruderals (CR) and CSR-strategists, some as stress tolerant competitors (SC)[4]. However, the most spectacular change in taxonomic composition took place in *Melastomataceae*. The majority of the representatives of the plant family with the most species present on the area before clearence did not regenerate. The only genus of *Melastomataceae* found frequently on the area after slashing and burning is *Clidemia*, above all *Clidemia hirta* (L.) D. Don., a shrub which regenerates quickly by seeds and vegetatively from roots and shoots. In *Bignonaceae* there are many lianas, shrubs and small trees which obviously regenerate or evolve, so the latter familiy is that one with the most species after clearance.

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[4] The classifictation involves specific types of growth form, behaviour of growth and regeneration. For details see Grime (1979), for a review Preisinger (1991).

Table 2 lists the 30 species (of 312), which occur most frequently in the experimental area one year after clearance. The majority of these species are herbs, grasses, shrubs and only a few small trees. The most frequently occurring shrubs are *Clidemia hirta* (*Melastomataceae*) and *Trema micrantha* (*Ulmaceae*). The liana *Pueraria phaseoloides* was sown as a cover crop in former times. It regenerated quickly after clearance and is now one of the herbaceous plants with the highest biomass production. The tree that accumulated the highest overground biomass production after clearance is *Vismia guianensis* (*Clusiaceae*).

Table 2:

Most frequent occurring species in 71 plots analysed (of 90) in the experimental area

frequency [%]	species (*family*)
92	Homolepis aturensis (H.B.K.) Chase (*Poaceae*)
72	Croton miguelensis Ferg. (*Euphorbiaceae*)
69	Pueraria phaseoloides (Rosed.) Benth. (*Fabaceae*)
69	Clidemia hirta (L.) D. Don. (*Melastomataceae*)
68	Borreria verticillata (L.) G.F.W. Mey. (*Rubiaceae*)
62	Trema micrantha (L.) Blume (*Ulmaceae*)
62	Panicum laxum Sw. (*Poaceae*)
61	Davilla latifolia Casar (*Dilleniaceae*)
61	Rolandra fruticosa (L.) Kuntze (*Asteraceae*)
59	Machaerium hoehnearum Ducke (*Fabaceae*)
59	Irlbachia alata (Aublet) Maas (*Gentianaceae*)
54	Cecropia spp. (*Moraceae*)
52	Solanum rugosum Dun. (*Solanaceae*)
49	Emilia sonchifolia D.C. (*Asteraceae*)
48	Vismia cayenennsis (Jacq.) Pers. (*Clusiaceae* = *Guttiferae*)
47	Borrerea latifolia (Aubl.) K. Schum (*Rubiaceae*)
47	Passiflora coccinea Aubl. (*Passifloraceae*)
45	Lantana camara L. (*Verbenaceae*)
45	Piper spp. (*Piperaceae*)
44	Vismia guianensis Choisy (*Clusiaceae* = *Guttiferae*)
44	Arrabidaea spp. (*Bignoniaceae*)
44	Pogonophora schomburgkiana Miers. (*Euphorbiaceae*)
44	Paspalum maritimum Trin. (*Poaceae*)
44	Scleria pterota Presl. (*Cyperaceae*)
42	Passiflora auriculata H.B.K. (*Passifloraceae*)
37	Cecropia leucocoma Mig. (*Moraceae*)
37	Caryophylla sp. (*Caryophyllaceae*)
37	Memora spp. (*Bignoniaceae*)
37	Chimarrhis spp. (*Rubiaceae*)
35	Panicum rudgei R. & S. (*Poaceae*)

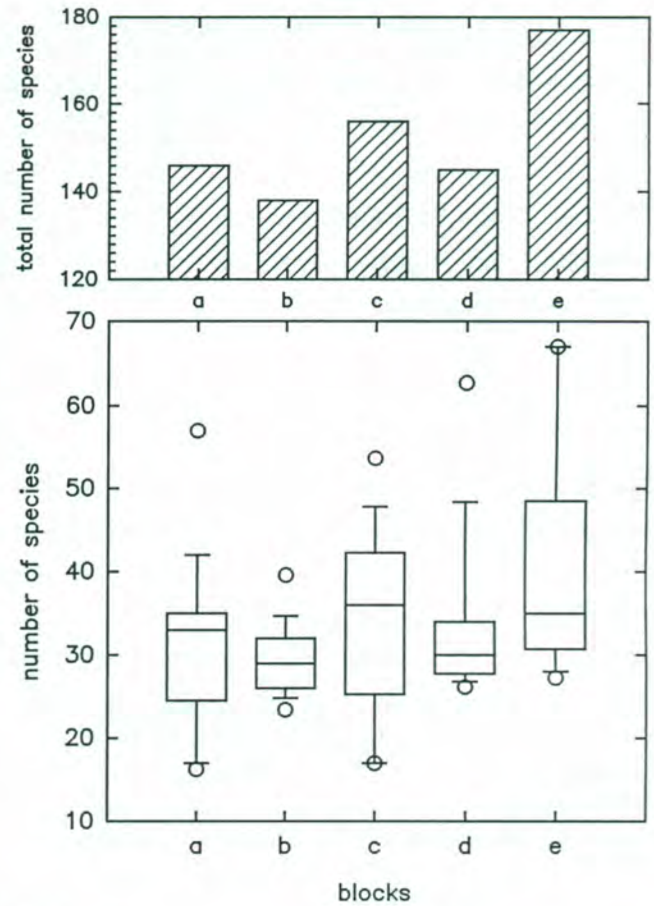

Fig. 6:
Total numbers (top) and median numbers of species (bottom, box plot) present in blocks a-e, the latter representing also 25/75th, 10/90th and 5/95th percentiles

The floristic analysis of 71 out of 90 plots revealed 312 species. Fig. 6 (top) displays the total numbers of species found in blocks a-e, showing a maximum in block e and a minimum in block b. To find out differences in the richness of species between the plots of five blocks, a one way analysis of variance was carried out (Kruskal-Wallis one way ANOVA on ranks). According to the test there are no statistically significant differences in the median values among the groups. Nevertheless, the bar chart and the box plot (Fig. 6) indicate a clear tendency of increasing maximum species numbers in the plots from block a to e (in particular see 90th and 95th percentiles of box plot). This increase can be explained by local migration of "opportunistic" (R-, CR- and CSR-) species which grow in patches, advancing from block e to block a, leaving the secondary forest species growing between. To find out differences in species richness between the different plantation systems, the same statistical test was carried out as mentioned above, comparing systems 1, 2, 3, 4, two monoculture plots (system 9, citrus) and the fallow plots. The Kruskal-Wallis-Test reveals a significant difference between system 1 and the fallow plots only. The results (Fig. 7) can be interpreted as *a tendency of increasing species richness with a decreasing extent of disturbance*[5]. System 1, showing the lowest species numbers, is the most "intensive", system 4 the most "extensive" agricultural system. The highest species numbers occur in the fallow plots, where after slashing and burning no further disturbance took place. The species numbers of the monoculture systems, which are

[5] A causality between richness of species and fertilization, respectively inoculation of mycorrhizal fungi spores, could be excluded by a test before.

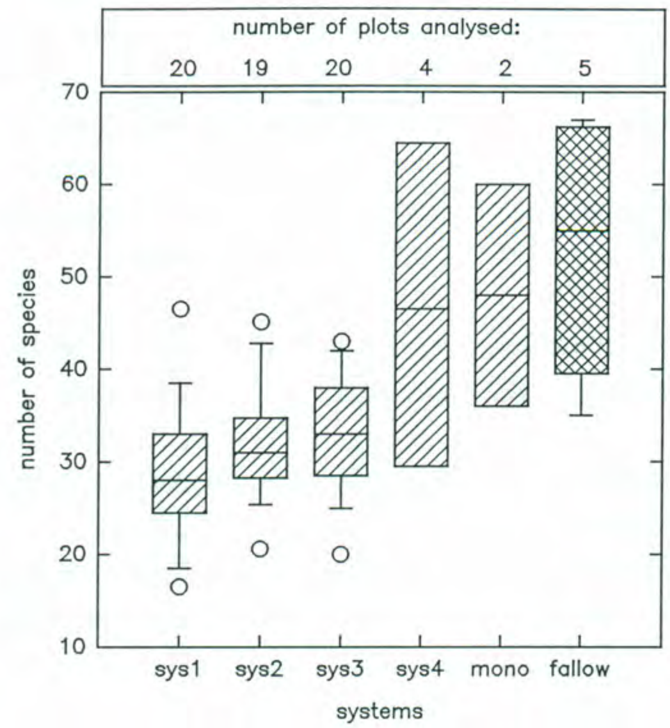

Fig. 7:
Median numbers of species present in the plantation systems 1, 2, 3, 4 and monoculture plots, compared to the fallow plots

similar to those in system 4, do not say much because there were only two plots analysed. Nevertheless, in the citrus monoculture plot there is much space left between the rows, and in contrast to systems 2 and 3 there are no short living and annual crops, which require more intensive management than perennial plants. Hence, disturbance in the monocultural systems may be lower than in the mixed culture systems.

4 Conclusions

The evaluation of the data was carried out to describe the spatial differences of selected traits of vegetation structure and floristic composition. The analysis detected a complex spatial environmental gradient, which needs a more detailed, multi-variate analysis (Preisinger, Siqueira & Coelho, *in preparation*).

The gradient is directed from block a to block e. The plots of block e show distinct characteristics different from the others (in particular the presence of bracken, *Pteridium aquilinum*). Trees dominate in blocks a, b and in some plots of c and rhizome/tussock grasses and ferns dominate in block e. The number of species found rises from block a to block e, due to an increasing number of herbaceous plant species, which spread by rhizomes, runners or seeds and invade the agricultural area from the south-eastern side. This pattern indicates differences in intensity and duration of past agricultural use. Agricultural experiments in the south-eastern part of the area (blocks e, d and partly c) started in 1982, the north western parts (blocks a, b and partly c) in 1985 (cf. *Tavares, Preisinger & Martins*).

A comparison of species richness between the different plantation systems indicates a tendency of decreasing species numbers with increasing intensity of present use, or disturbance respectively. In particular there is a decrease in woody species. Absence of a species means absence of overground biomass, indicating that the period between the events of disturbance (cutting and hoeing) is not long enough for regeneration. As a consequence, sustainable agricultural use of the area would lead to a non reversable change of vegetation cover, which would mean a loss of biodiversity of forest species in the sites. In contrast, shifting cultivation in the eastern Amazon (Zona Bragantina), which lasts about 90 years, did not destroy the potentiality of secondary forest species (see Denich 1989; Denich, Socorro & Kato 1993, Baar & Conceição 1993).

In principle there are three ways of controlling growth of wild vegetation in the plantation. These favour different eco-morphological plant types or strategy types:

1. The secondary vegetation is allowed to regenerate, but is occasionally cleared around the useful plants (minimum management), as practised in plantation system 4. In this case mainly trees, i.e. long living growth forms, would benefit, but the species spectrum might be compressed owing to the occasional disturbance.

2. The cultivation area is kept free of taller growth forms, i.e. the regeneration of secondary forest species is frequently disturbed by cutting and hoeing, as practised in systems 1, 2 and 3 and in the monoculture blocks. This benefits, in particular, long lived grasses (strategy types "Competitive Ruderals" CR and "Stress tolerant Competitors" SC).

3. Lianas of the CR strategy type are sown, which was done for the first time in the former rubber plantation in the test area (*Pueraria phaseoloides*). This leads to species-poor sites, dominated by the Competitive Ruderal plant species.

The response of a species to disturbance can roughly be indicated from its spatial pattern of distribution, if there is knowledge available of past disturbance events on the sites under study. The oberservation, that the species which invade an area after severe disturbance have much in common with species growing on similar sites in the temperate regions of the world, indicates that the mechanisms responsible for vegetation patterns are similar as well. Therefore, CSR-theory can be applied to this vegetation. In contrast, the mechanisms responsible for the pattern of primary and secondary forests are different from those occurring in temperate regions. Therefore successional processes in secondary forest can only be described in part by the CSR model. This is even more true of succession mechanisms in primary forest, which in part fall outside the scope of the theory.

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Untersuchungen zum Vorkommen und Einsatz von vesikulär-arbuskulären Mykorrhizapilzen (VAM) auf der Versuchsplantage des SHIFT-Projekts bei Manaus-AM

Elke Idczak

Resumo:

Estudos sobre a ocurrência e uso de fungos micorrizicos vesicular-arbusculares na área experimental do projeto SHIFT, proxima a Manaus-AM

Em 1992, para estabelecer o experimento em condições de campo, as mudas das plantas úteis foram inoculadas ou não com fungos micorrízicos vesicular - arbusculares (MVA). Foi analisado o grau de colonização das raízes pelo fungo MVA. As plantas micorrizadas, geralmente, apresentaram crescimento superior, e as taxas de perdas dessas plantas, no campo, foram inferiores às plantas não inoculadas. As plantas de seringueiras inóculadas com fungos MVA foram menos afetadas por doenças, demonstrando os benefícios dos fungos micorrízicos na agricultura tropical. Até o período de plantio, seis meses após a derruba e queima da área, o material infectivo dos fungos MVA estava presente no solo da área experimental. Isso explica a presença de fungos micorrízicos, após um período de cultivo do sexto ao nono mês, no campo em plantas úteis que não foram inoculadas no viveiro. O cultivo de milho e mandioca nos sistemas de policultivo favoreceu a micorrização das plantas utéis crescendo próximo, como por exemplo citros. O grau de colonização das raízes das plantas por fungos micorrízicos é significativamente superior nas plantas cítricas, nos sistemas de policultivo, quando comparado com as plantas da área de monocultivo. O fato do cultivo de milho e mandioca poder melhorar a micorrização de outras plantas crescidas próximas a elas, permite concluir que elas, indiretamente, inoculam aquelas plantas e portanto, atuam como "plantas armadilhas".

Summary:

Studies on presence and use of vesicular-arbuscular micorrhizal fungi (VAM) in the experimental site of the SHIFT project near Manaus-AM

In 1992 the roots of the useful plants grown for the experimental plantation were inoculated with vesicular-arbuscular mycorrhizal fungi in the nursery of the CPAA, others were left uninoculated as controls. The degree of root colonization by the symbiotic partner was analysed. The mycorrhizal plants generally revealed a slight advantage in plant growth, and the loss rate of these plants after planting into the field was lower than for the control plants. The inoculated rubber tree plants were less taken *by phytopathological fungi than the control plants, which demonstrates the benefits of mycorrhizal fungi in tropical agriculture. At the time of planting, six months after slashing and burning, infective material of vesicular-arbuscular mycorrhizal fungi was proved to be present in the soil of the experimental area. This explains, why useful plants, to which no VAM-inoculum had been applicated, were mycorrhizal after a cultivation period of six to nine months in the field. The cultivation of corn and cassava in polycultural systems shows a positive effect on the mycorrhization of useful plants grown nearby, for example citrus. The degree of root colonization by mycorrhizal fungi is significantly higher for citrus plants grown in polycultural systems compared to monocultures. The fact that the cultivation of corn and cassava can improve the mycorrhization of other plants grown close to them leads to the conclusion that they indirectly inoculate those plants and therefore act as "nurse plants".*

1 Einleitung

Bei der Untersuchung von Faktoren, die die zeitliche Stabilität einer Pflanzung beeinflussen können, stellen Mikroorganismen einen bedeutenden Gesichtspunkt dar. Dies gilt insbesondere für solche Mikroorganismen, die zur Steigerung der Vitalität von Pflanzen beitragen, wie es hinreichend für vesikulär-arbuskuläre Mykorrhizapilze (VAM) belegt ist (Schönbeck 1980).

Aus diesem Grund wurden auf der für die Pflanzung vorbereiteten Versuchsfläche Studien zum Vorkommen von Mykorrhizapilzen durchgeführt. Eine grobe Klassifizierung der Pilze schloß sich daran an.

Des weiteren wurden die verwendeten Kulturpflanzen, die in einem Teil der Versuchsansätze vorab mit VA-Mykorrhizapilzen inokuliert wurden, auf den Grad der Wurzelbesiedelung durch den pilzlichen Symbiosepartner hin kontrolliert. Der Einfluß der VAM auf das Wachstum und die Gesundheit der Kulturpflanzen wird über den Vergleich der mit den Mykorrhizapilzen inokulierten Pflanzen und der nicht inokulierten Kontrollpflanzen für beide der im Experiment verwendeten Düngungsstufen (30% bzw. 100% der empfohlenen Düngermenge) ermittelt. Ein anderer Bereich der Untersuchungen bezieht sich auf die Frage, inwieweit eine Vermehrung der Mykorrhizapilze im Feld erfolgreich sein könnte und ob eine Inokulierung nicht-mykorrhizierter Kulturpflanzen über den Anbau sogenannter "nurse-plants" in deren Nachbarschaft durchgeführt werden könnte. Bei diesen "nurse-plants" handelt es sich um schnellwüchsige Wirtspflanzen der Mykorrhizapilze wie z.B. Mais, Bohnen oder Maniok, deren besiedeltes Wurzelsystem eine Inokulumsquelle für nicht-mykorrhizierte Pflanzen darstellt.

2 Material und Methoden

Zur Ermittlung der im Boden vorhandenen Anzahl an VA-Mykorrhizapilzsporen wurden Bodenproben von 10x10x10 cm^3 Volumen gezogen. Die Aufarbeitung von je 50 cm^3 dieser Proben erfolgte über Naßsiebung und Zentrifugation (Methode verändert nach Daniels uns Skipper 1984). Die einzelnen Bodenproben wurden jeweils sechsmal mit Wasser aufgeschwemmt und nach der Sedimentation der schweren Bodenbestandteile (10 sec) wurde die Bodenlösung über eine Siebkombination von 425μm und 45μm Maschenweite gegeben. Die Rückstände aus dem Sieb mit 45μm Maschenweite wurden in 40%ige Saccharoselösung überführt und 15 sec bei 1400 x g zentrifugiert. Nach der Zentrifugation befinden sich die Sporen im Überstand. Zur Klassifizierung der Sporen wurden Dauerpräparate für die Mikroskopie angefertigt und die Sporen zum Teil fotografiert.

Zur Bestimmung der wahrscheinlichsten Zahl an Infektionseinheiten von VAM-Pilzen im Boden wurde der MPN-Test nach Feldmann & Idczak (1992) mit Mais als Testpflanze durchgeführt.

Die Anfärbung von Wurzelproben auf Pilzbesiedelung erfolgte nach Philipps & Hayman (1970). Für eine optimale Anfärbung wurden die Behandlungszeiten der Wurzeln mit den verschiedenen Substanzen für die unterschiedlichen Pflanzenarten variiert. Die anschließende Bestimmung des Wurzelbesiedelungsgrades bzw. der Besiedelungsintensität erfolgte nach Idczak (1992).

Die exakte Probenahme von Wurzeln aus dem Feld ist problematisch, da die Wurzeln unterschiedlicher Pflanzenarten ineinander verflochten sind und eine Zuordnung zur jeweiligen Testpflanze oft schwierig ist. Um die Identifizierung der Wurzeln im Feld zu erleichtern, wurden bereits in der Baumschule Wurzelproben der verschiedenen Kulturpflanzen entnommen. Die Wurzelsysteme wurden fotografiert, getrocknet und für spätere Vergleiche gelagert. In vielen Fällen geben bereits Färbung und Verzweigungsmuster der Wurzeln Aufschluß über die jeweilige Pflanzenart. Die Probenahme im Feld erfolgte immer dicht an der Sproßachse, um möglichst noch die Verbindung der Wurzeln zum Sproß nachweisen zu können. Da eine größere Störung der Pflanzen vermieden werden sollte, wurden nur oberflächennahe Wurzeln (bis 10cm Tiefe) entnommen.

Um eine genauere Untersuchung der Wurzelsysteme von Kulturpflanzen im Feld zu ermöglichen, ohne dabei Pflanzen aus der Plantage entfernen zu müssen, wurde eigens zu diesem Zweck eine gesonderte Pflanzung angelegt. Verwendet wurden: Cupuaçu, Urucum, Castanha do Brasil, Seringueira, Andiroba, Citrus, Paricá, Coco und Pupunha.

Für Cupuaçu und Urucum wurden die Varianten Mykorrhizapilz-inokuliert (+M) und nicht-inokuliert (-M) jeweils bei 30% und 100% der empfohlenen Düngermenge gepflanzt. Die anderen Pflanzenarten wurden ausschließlich mit 30% der empfohlenen Menge gedüngt (jeweils +M und -M; Ausnahme Paricá, ausschließlich -M). Da die Ausbringung dieser Pflanzen erst im Anschluß an die Pflanzung auf der Experimentalfläche und somit erst zum Ende der Regenzeit erfolgte, ist die Entwicklung der Pflanzen nicht direkt miteinander vergleichbar. Die typischen Eigenschaften der Wurzelsysteme, wie z.B. der Verzweigungsmodus, dürften davon aber unbeeinflußt bleiben. Zur Untersuchung der Wurzelsysteme dieser Pflanzen s. *Voß*.

Die Kulturbedingungen für die einzelnen Pflanzenarten sind dem Berichtsteil von *Macedo* zu entnehmen.

3 Ergebnisse

3.1 Mykorrhizasituation im Feld zum Zeitpunkt der Pflanzung

Um festzustellen, auf welche Bedingungen hinsichtlich des Vorkommens von VA-Mykorrhizapilzen die Kulturpflanzen bei Ausbringung ins Feld - also nach der Brandrodung - stoßen, wurden im März 1993 dreißig Bodenproben über die Gesamtfläche der Plantage verteilt entnommen (je eine Probe aus sechs Parzellen pro Block). Die Analyse dieser Proben ergab, daß in einem Kubikzentimeter Boden 2-16 VA-Mykorrhizapilzsporen enthalten sind und damit eine relativ homogene Verteilung der Mykorrhizapilze auf der Experimentalfläche vorliegt (s. Abb.1). Es kann allerdings nicht ausgeschlossen werden, daß schon in kleineren Bereichen (z.B.im Quadratmetermaßstab) größere Schwankungen bezüglich der Anzahl von VAM-Sporen auftreten. Um diese Frage zu klären, wurden an zwei Stellen der Experimentalfläche je fünf Bodenproben innerhalb eines Quadratmeters entnommen. Am ersten Probenahmeort, der wie die über die Gesamtfläche verteilten 30 Probenahmestellen keinen Pflanzenbewuchs aufwies, schwankte die Zahl der VAM-Sporen zwischen 1,5 und 3,6 Sporen/cm^3 Boden. Beim zweiten Ort der Probenahme, bei dem eine dichte Pflanzendecke vorlag, lagen die Werte für vier der fünf Proben zwischen 5,2 und 11,2 Sporen/cm^3, die fünfte Probe wies jedoch mit 69,5 Sporen/cm^3 einen völlig davon abweichenden Wert auf. Bei einer mit Pflanzen bewachsenen Fläche muß also mit derartig großen Unterschieden gerechnet werden. Die Daten, die für die Sporenverteilung auf der Gesamtfläche ermittelt wurden, können daher nur eine annähernde Vorstellung von der tatsächlichen Verteilung der VAM-Sporen geben.

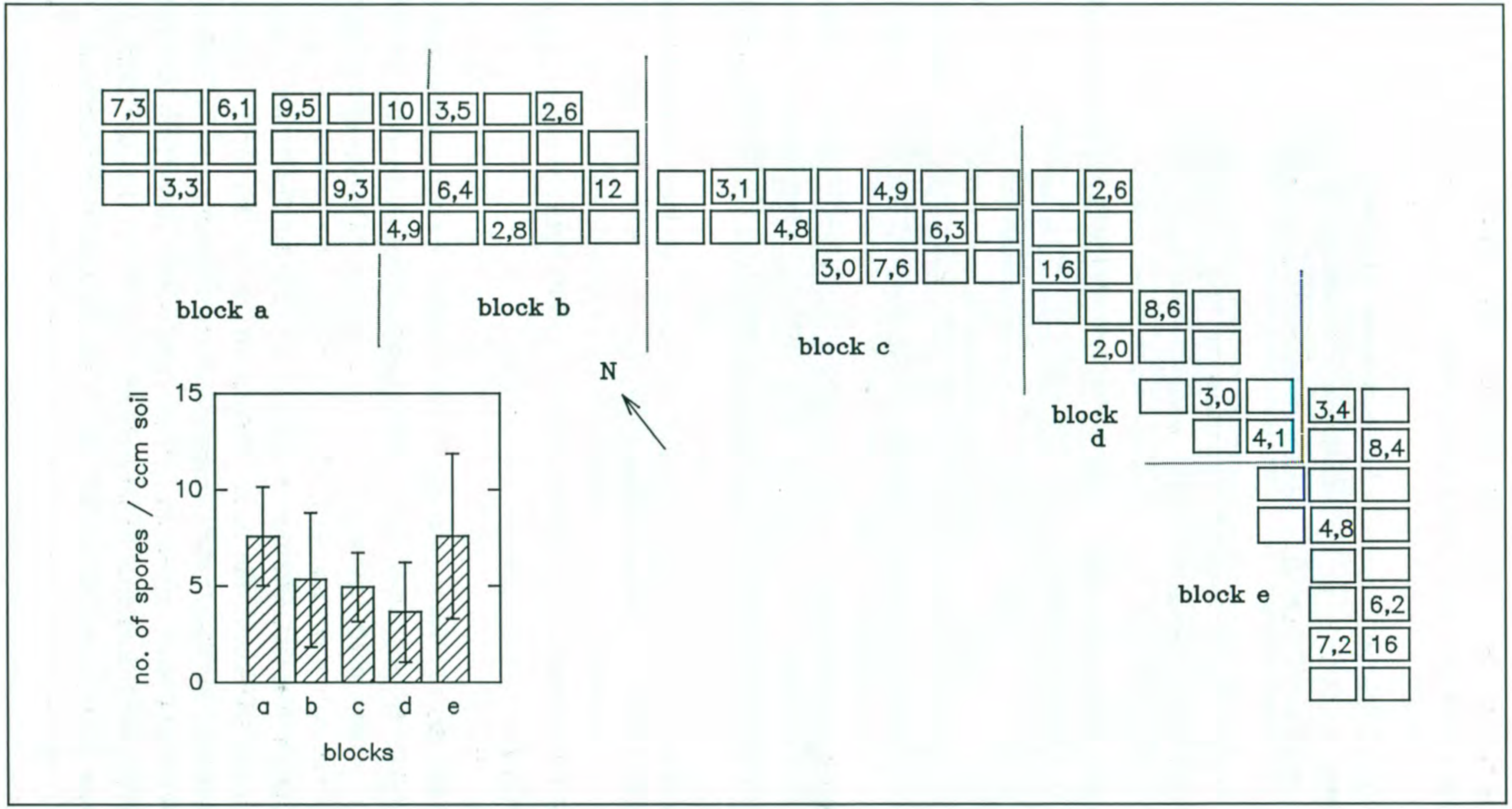

Abb. 1:

Vorkommen von VAM-Sporen auf der Testfläche und aritmetische Mittelwerte für die Blöcke a-e und Standardabweichung (Einsatz-Graphik); analysierte Parzellen mit Anzahl der Sporen/cm³ Boden

Zur qualitativen Analyse der auf der Versuchsfläche vorhandenen VAM-Pilze wurden die aus dem Boden extrahierten Sporen grob klassifiziert:

- *Glomus sp. a*: gelbe bis braune Färbung; ovale, seltener runde Form; Sporendurchmesser 69-82 x 74-115μm; Wanddicke 8μm; eine Wandgruppe; sowohl intraradiculäre Sporen als auch Sporokarpien dieses Pilzes wurden gefunden.

- *Glomus sp. b*: goldgelbe Färbung; runde bis unregelmäßige Form; Sporendurchmesser 92-113μm; Wanddicke 5-9μm; zwei Wandgruppen.

- *Glomus sp. c*: hyaline Sporen; ovale bis unregelmäßige Form; Sporendurchmesser 55-65 x 60-103μm; Wanddicke 2-5μm.

- *Scutellospora sp. a*: hyaline bis weiße Färbung; rund bis unregelmäßig geformt; Sporendurchmesser 370μm (bzw. 300 x 380μm); Wanddicke 13 μm; Suspensor 65-103μm; Scutellum rötlich bis braun gefärbt; mindestens zwei Wandgruppen.

- *Scutellospora sp. b*: braune Färbung; runde Form; Sporendurchmesser 270μm (Angabe basiert nur auf wenigen Messungen, da kaum Material dieser Sporen vorlag); Wanddicke 12μm; zwei Wandgruppen; Scutellum dunkelbraun gefärbt.

- *Acaulospora sp.*: braune Färbung; runde Form; Sporendurchmesser 180-280μm; Wanddicke 12μm; zwei Wandgruppen.

- Sonstige: Pilzsporen, die von den bisherigen Beschreibungen abweichen und nur in geringer Anzahl vorliegen.

Sporen von *Glomus sp. a* kamen in jeder der 30 Bodenproben vor und machten mit 53 bis 98% den jeweils größten Anteil der Gesamtsporenzahl aus (siehe Abb. 2). Der zweite Sporentyp wurde in 24 Proben nachgewiesen. In diesen Proben schwankt der Anteil dieser Sporen zwischen 1 und 43%. Die dritte *Glomus*-Art ist in 23 Proben mit bis zu 21% enthalten. Nur aus sechs der 30 Bodenproben wurden Sporen der Gattung *Scutellospora* (a und b) isoliert, die maximal einen Anteil von 3% an der Gesamtsporenzahl ausmachen. Die Sporen der Gattung *Acaulospora* konnten erst bei späteren Untersuchungen dieser Gattung zugeordnet werden und wurden daher zum Zeitpunkt der Quantifizierung und aufgrund ihrer geringen Anzahl der Klasse "Sonstige" zugeordnet, deren Anteil sich im Mittel auf 6% der Gesamtsporenzahl beschränkt.

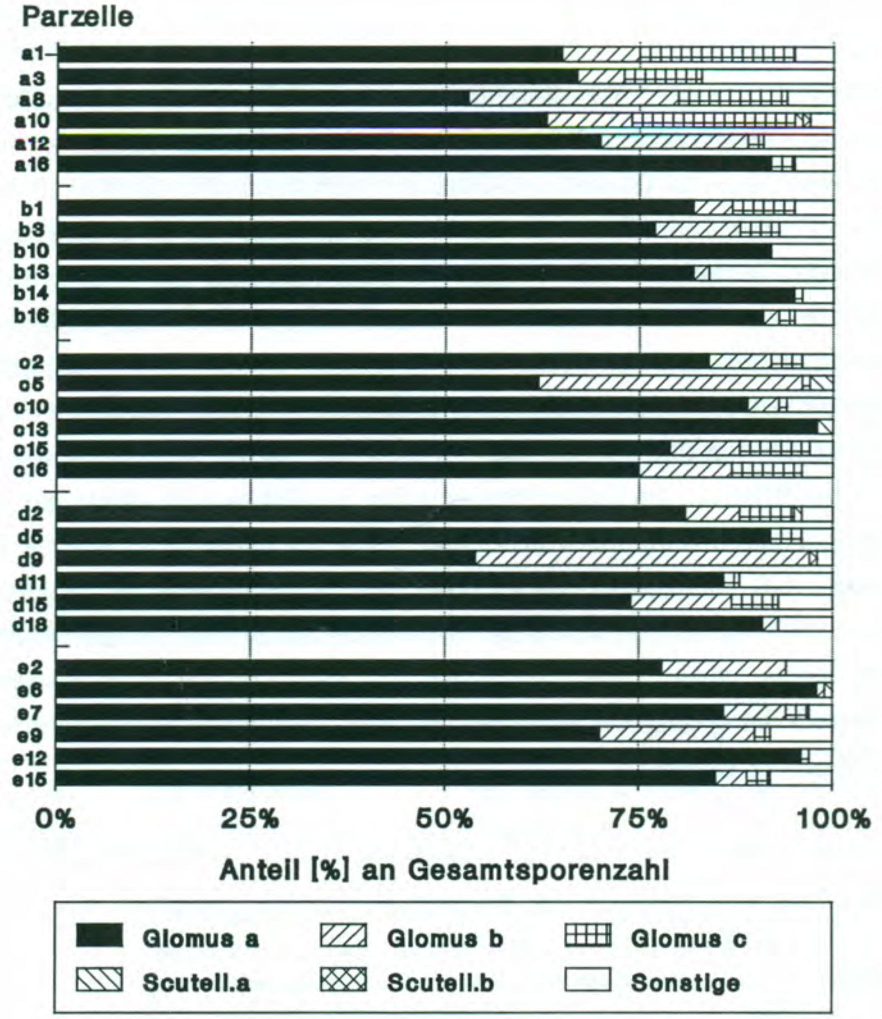

Abb. 2:
Verteilung unterschiedlicher Sporentypen vesikulär-arbusculärer Mykorrhizapilze auf den untersuchten Parzellen der Experimentalfläche

Das Vorkommen von Mykorrhizapilzsporen im Boden läßt noch keine Aussage über ihre Infektiosität zu. Die Keimfähigkeit der Sporen kann erheblich durch die Brandrodung beeinträchtigt sein. Inwieweit infektiöses Pilzmaterial im Boden vorliegt, kann durch einen MPN-Test (Most-Probable-Number-Test) geklärt werden. Jeweils im März und April, also zum Zeitpunkt der Pflanzung, wurde ein Test mit Bodenmischproben vom Feld durchgeführt. Beide Tests ergaben, daß keinerlei infektiöses Mykorrhizapilzmaterial im Boden vorhanden ist. Allerdings wurde als Testpflanze standardmäßig nur Mais eingesetzt. Bei Verwendung einer anderen Pflanzenart kann das Testergebnis durchaus anders ausfallen (Idczak 1992). Das besonders schnelle

Wachstum des Mais unter den tropischen Bedingungen ist für den MPN-Test eher als hinderlich zu bewerten. Eine Anpassung des Tests an die gegebenen Bedingungen ist wünschenswert aber sehr langwierig.

Um zu überprüfen, ob im Feld tatsächlich kein infektiöses Mykorrhizapilzinokulum vorliegt, wurden Wurzelproben von Pflanzen der Sekundärvegetation mit unterschiedlichen Wuchsformen (siehe auch Bericht Preisinger) vom Feld entnommen und auf Besiedelung mit VAM-Pilzen hin kontrolliert. In jeder der Pflanzengruppen bzw. -arten wurde eine - wenn auch sehr geringe - Mykorrhizierung der Wurzeln festgestellt (Tab. 1). Die niedrigen Besiedelungsgrade könnten darauf hinweisen, daß nur ein sehr geringes Infektionspotential der VAM-Pilze im Boden vorhanden ist. Allerdings kann oft schon eine einzige Infektionseinheit zu einer starken Wurzelbesiedelung führen. Dies hängt grundsätzlich von den genetischen Anlagen der beiden Symbiosepartner ab. Bei den untersuchten Pflanzen der Sekundärvegetation handelt es sich möglicherweise nicht um besonders geeignete Wirtspflanzen der autochtonen VA-Mykorrhizapilze. Es ist aber auch bekannt, daß das Infektionspotential von VAM-Pilzen im Boden starken jahreszeitlichen Schwankungen unterliegt, wie von Gemma (1987) durch Ermittlung von Sporenzahlen belegt wurde. Erste Ergebnisse zum Mykorrhizierungsgrad der Wurzeln von Pflanzenarten der spontanen Vegetation der Versuchsfläche deuten ebenfalls darauf hin (s. *Figueiredo & Oliveira*).

Tab. 1:
Wurzelbesiedelung von Pflanzen der Sekundärvegetation durch VA-Mykorrhizapilze (Analyse von je drei Wurzelproben pro Pflanzenart bzw. Wuchsform)

Wuchsform/Pflanzenart	Wurzelbesiedlungsgrad [%]
Ausläufergräser	< 1
Horstgräser	< 1
Farne (*Pteridium aquilinum*)	< 1
Bäume (*Vismia guianensis*)	< 1
Lianen u. Kräuter m. kriech. Wuchsf. (*Pueraria phaseoloides*)	10-20

In jedem Fall aber ist nachgewiesen, daß im Feldboden infektiöses VAM-Pilzinokulum vorliegt und damit eine Konkurrenzsituation zu den Mykorrhizapilzen entsteht, die über die inokulierten Kulturpflanzen in die Plantage eingebracht werden. Inwieweit das im Feld vorhandene Inokulum die Wurzelbesiedelung der Kulturpflanzen beeinflußt, wird im folgenden Kapitel dargestellt.

3.2 Wurzelbesiedelung der Nutzpflanzen im Kulturverlauf und Einfluß der Symbiose auf Wachstum und Vitalität der Pflanzen

Die Wurzelbesiedelungsdaten der Kulturpflanzen zum Zeitpunkt der Pflanzung sind in Tabelle 2 zusammengefaßt. Für einige der Pflanzenarten konnte weder bei Kontrollpflanzen noch bei Mykorrhizapilz-inokulierten Pflanzen eine Besiedelung der Wurzeln durch die Pilze nachgewiesen werden. Beim Kautschuk dürfte dies darauf zurückzuführen sein, daß die Pflanzen zu einem Zeitpunkt inokuliert wurden, zu dem die verwendeten "tocos" noch keine Wurzeln ausgebildet hatten. Bei Ausbildung der Wurzeln war das Pilzinokulum möglicherweise nicht mehr infektiös. Die Citruspflanzen wurden vom Händler bezogen und erst bei Pflanzung ins Feld mit VAM-Pilzen inokuliert. Zum Zeitpunkt der Auspflanzung waren sie nicht mykorrhiziert. Aus welchem Grund die Wurzeln der beiden Palmenarten nicht besiedelt waren, ist unbekannt.

Tab. 2:
Wurzelbesiedelung der Kulturpflanzen durch VA-Mykorrhizapilze zum Zeitpunkt der Ausbringung ins Feld

Pflanzenart	Probenumfang [n Pflanzen]	Wurzelbesiedlungsgrad [%] -M / +M	Besiedlungsintensität -M / +M
Coco	3	0 / 0	- / -
Citrus	10	0 / -	- / -
Pupunha	5	0 / 0	- / -
Seringueira	5	0 / 0	- / -
Castanha-do-B.	12*	0 / <1	- / 1,0
Cupuaçu	5	0 / 1	- / 1,3
Mamão	3	0 / 42	- / 1,8
Mogno	3	8 / 35	1,1 / 1,1
Paricá	5*	26 / 61	1,6 / 1,4
Urucum	5	31 / 59	1,3 / 1,8
Andiroba	3	42 / 10	1,2 / 1,0

* = Mischproben (sonst Einzelproben); -M = Kontrollpflanzen, die nicht mit Mykorrhizapilzen inokuliert wurden; +M = Pflanzen, die mit Mykorrhizapilzen inokuliert wurden

Bei allen anderen Pflanzenarten wurde eine Wurzelbesiedelung der inokulierten Pflanzen festgestellt. Zum Teil waren auch Kontrollpflanzen mykorrhiziert. Dies beruht auf der Verwendung von unsterilisiertem Boden bei der Pflanzenanzucht, der offensichtlich infektiöse Einheiten von VAM-Pilzen enthielt. Generell war die Wurzelbesiedelung der inokulierten Pflanzen jedoch höher als die der Kontrollpflanzen. Ausgenommen davon ist lediglich Andiroba. Sämlinge dieser Pflanzenart wurden 1992 direkt aus dem Naturwald entnommen. Möglicherweise waren diese Sämlinge bereits mykorrhiziert. Die darauffolgende Inokulation mit weiteren VAM-Pilzen könnte eine Konkurrenzsituation herbeigeführt haben, die letztlich in einer geringeren Wurzelbesiedelung der inokulierten Pflanzen im Vergleich zu den Kontrollpflanzen resultiert.

Einige der Kulturpflanzen wurden Ende 1993 erneut auf die Besiedelung der Wurzeln durch VAM-Pilze hin überprüft (Abb. 3-8). Dabei sind zum Teil große Unterschiede zwischen den Pflanzen der verschiedenen Blöcke festzustellen. Generell zeichnet sich jedoch ab, daß hinsichtlich des Wurzelbesiedelungsgrades keine deutlichen Unterschiede mehr zwischen inokulierten und nicht-inokulierten Pflanzen bestehen. Offensichtlich hat eine Besiedelung der Kontrollpflanzen durch die im Feldboden vorhandenen Mykorrhizapilze stattgefunden. Lediglich beim Maniokkultivar IM 226 sowie beim Mais ist bei der niedrigen Düngungsstufe eine stärkere Besiedelung der inokulierten Pflanzen nachzuweisen als für nicht-inokulierte Pflanzen.

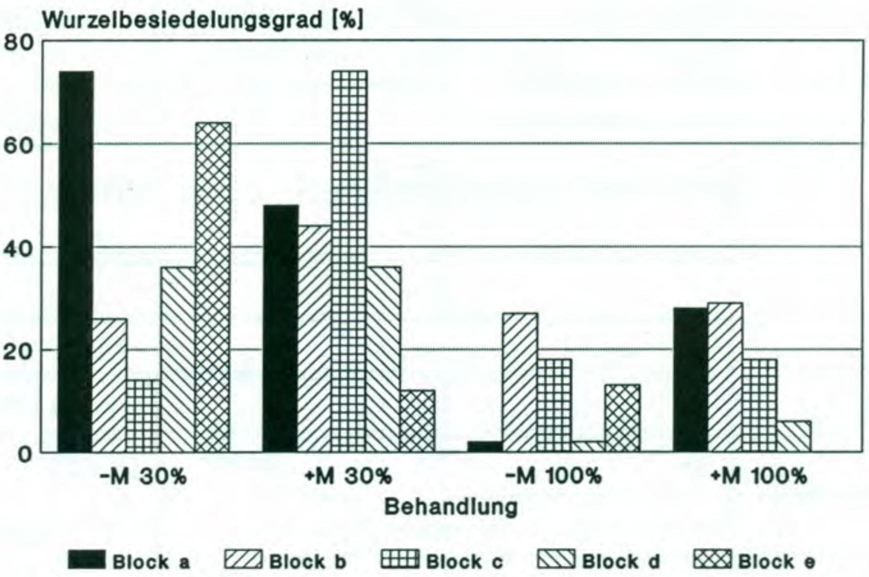

Abb. 3:

Besiedelung der Wurzeln von Mamão durch VAM-Pilze.

Die Probenahme der Wurzeln erfolgte sieben Monate nach der Pflanzung. Jeder Balken repräsentiert das Resultat der Analyse einer Wurzelmischprobe von drei Pflanzen.

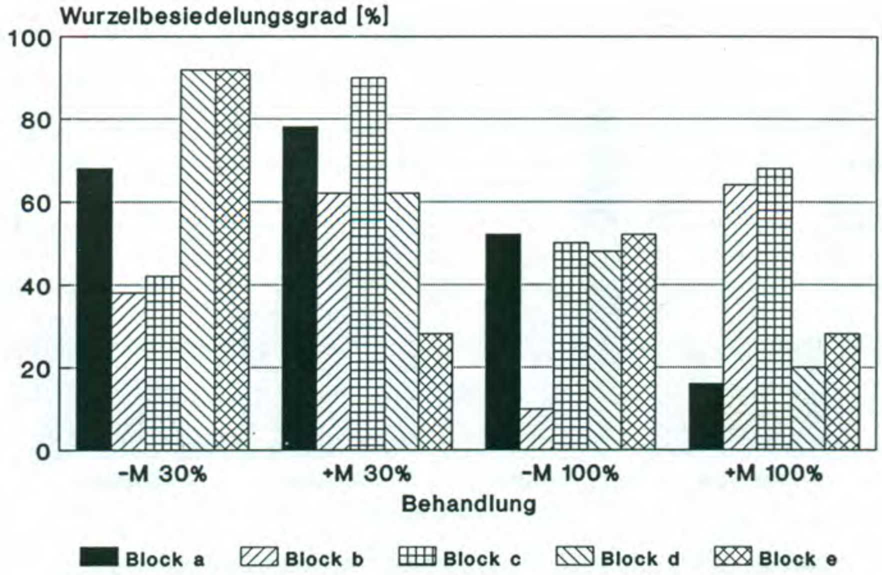

Abb. 4:

Besiedelung der Wurzeln von Urucum durch VAM-Pilze.

Die Probenahme der Wurzeln erfolgte acht Monate nach der Pflanzung. Jeder Balken repräsentiert das Resultat der Analyse einer Wurzelmischprobe von drei Pflanzen.

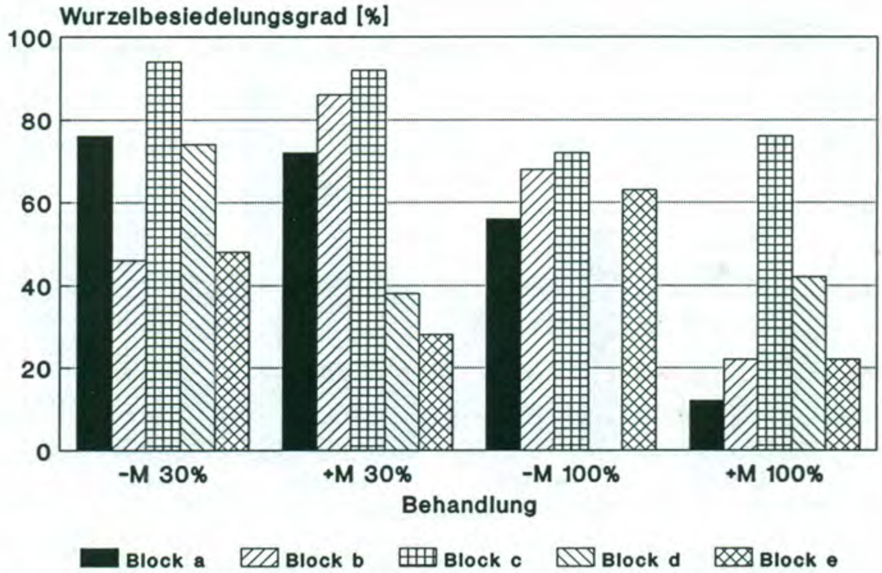

Abb. 5:

Besiedelung der Wurzeln von Citrus durch VAM-Pilze.

Die Probenahme erfolgte neun Monate nach der Pflanzung. Jeder Balken repräsentiert das Resultat der Analyse einer Wurzelmischprobe von drei Pflanzen.

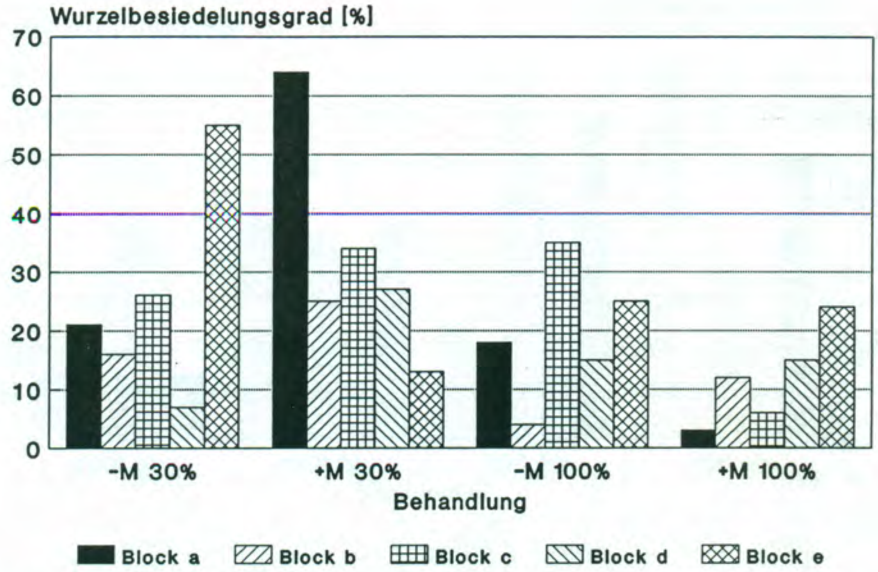

Abb. 6:
Besiedelung der Wurzeln von Mais durch VAM-Pilze.
Die Probenahme der Wurzeln erfolgte zwei Monate nach der Aussaat. Jeder Balken repräsentiert das Resultat der Analyse einer Wurzelmischprobe von drei Pflanzen.

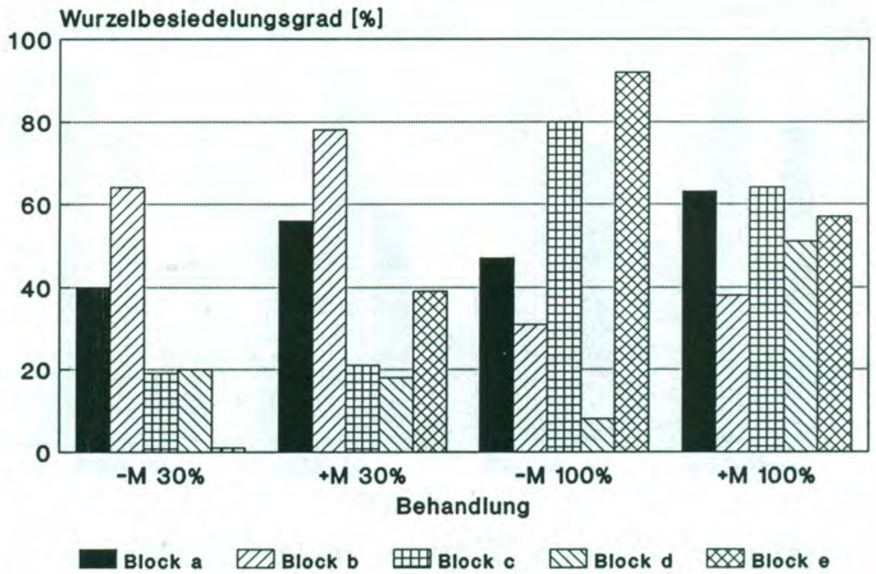

Abb. 7:
Besiedelung der Wurzeln von Maniok (Kultivar 116) durch VAM-Pilze.
Die Probenahme der Wurzeln erfolgte sechs Monate nach der Pflanzung. Jeder Balken repräsentiert das Resultat der Analyse einer Wurzelmischprobe von drei Pflanzen.

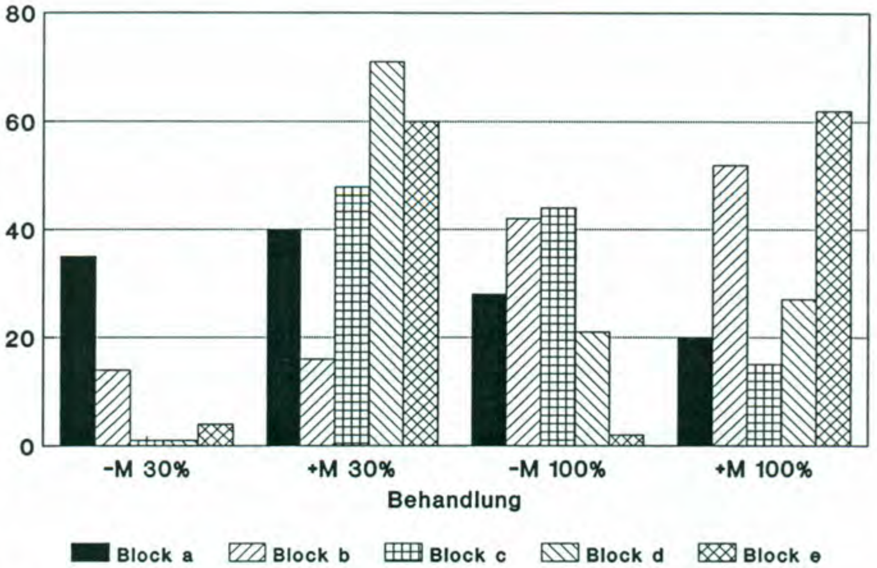

Abb. 8:
Besiedelung der Wurzeln von Maniok (Kultivar 226) durch VAM-Pilze
Die Probenahme der Wurzeln erfolgte sechs Monate nach der Pflanzung. Jeder Balken repräsentiert das Resultat der Analyse einer Wurzelmischprobe von drei Pflanzen.

Für Urucum und Mamão fällt zudem auf, daß der Wurzelbesiedelulngsgrad der stärker gedüngten Pflanzen (100%) niedriger ist als der der Pflanzen, die mit nur 30% der empfohlenen Düngermenge behandelt wurden. In geringerer Ausprägung gilt dies auch für Citrus und Mais. Das Phänomen, daß höhere Düngergaben - insbesondere an Phosphat - die Mykorrhizierung der Pflanzen beeinträchtigen, ist bereits aus der Literatur bekannt (Hung et al. 1987).

Ein Einfluß der Inokulierung der Kulturpflanzen mit Mykorrhizapilzen auf das Wachstum der Pflanzen war schon bei der Anzucht in der Baumschule festzustellen (siehe Jahresbericht 1992). Die inokulierten Pflanzen waren größer als die Kontrollpflanzen und wiesen eine größere Anzahl an Blättern auf. Sofern keine Mykorrhizierung der Pflanzen stattgefunden hatte (Cocos, Pupunha und Seringueira), war kaum eine Verbesserung des Wachstums festzustellen. Lediglich bei Seringueira übertraf die Höhe der inokulierten Pflanzen die der Kontrollpflanzen im Mittel um 10%. Möglicherweise befand sich die Mykorrhizierung der Pflanzen hier im Anfangsstadium. Bei der Aufarbeitung der Wurzeln für die mikroskopische Untersuchung werden Pilzhyphen auf der Oberfläche der Wurzeln leicht entfernt. Sofern erst vereinzelt Penetrationspunkte vorhanden sind, ist der Nachweis einer Mykorrhizierung oft in diesem Stadium nicht zu erbringen. Eine Förderung des Pflanzenwachstums könnte aber auch bereits durch die Keimung der Pilzsporen im Pflanzsubstrat bewirkt werden, da bei dem Keimungsvorgang Phytohormone von den Sporen abgesondert werden. Ein äußerst positiver Effekt der Inokulation der Pflanzen in der Baumschule erwies sich beim Umpflanzen ins Feld. Die Auspflanzverluste waren bei Mykorrhizapflanzen (+M) deutlich niedriger als bei den Kontrollpflanzen (s. Abb. 9). Die inokulierten Pflanzen sind offenbar weniger empfindlich gegenüber der Streßsituation beim Auspflanzen als nicht inokulierte Kontrollpflanzen. Die verminderte Streßanfälligkeit mykorrhizierter Pflanzen ist bereits in der Literatur belegt (Schönbeck 1980).

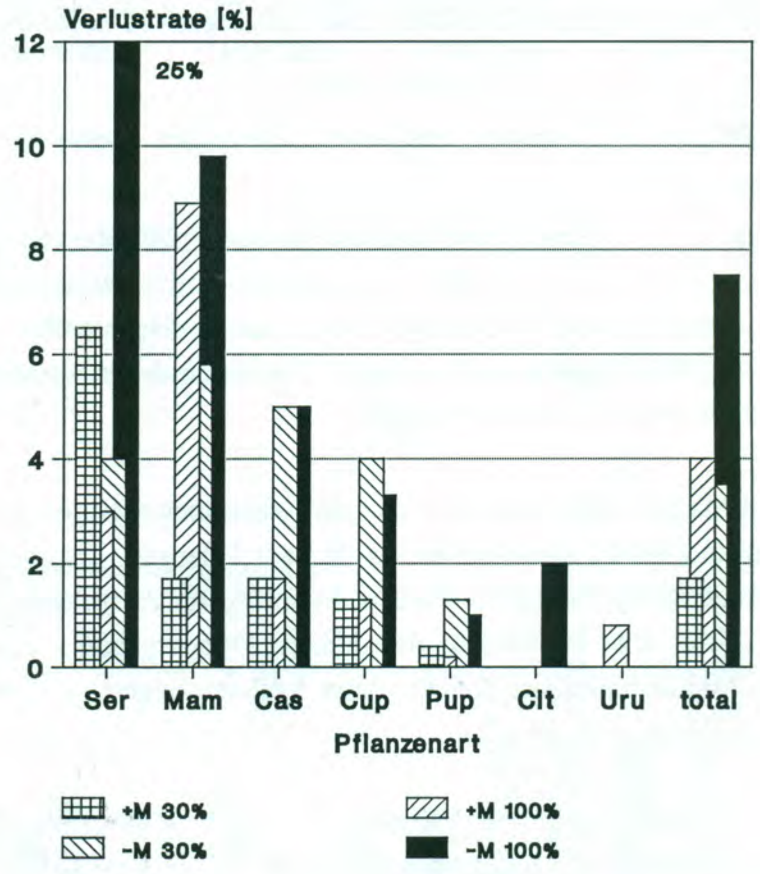

Abb. 9:
Auspflanzverluste bei vier Behandlungen von Seringueira (Ser), Mamão (Mam), Castanha-do-Brasil (Cas), Cupuaçu (Cup), Pupunha (Pup), Citrus (Cit), Urucum (Uru) und aritmetisches Mittel der Verlustrate aller Nutzpflanzen

Neben dem Umpflanzen stellt auch der Angriff durch phytopathogene Pilze einen Streßfaktor für die Pflanze dar. Im Fall von Seringueira wurde nachgewiesen, daß die Inokulation der Pflanzen mit Mykorrhizapilzen eine leichte Verminderung des Blattbefalls durch Schadpilze bewirkte (siehe Berichtsteil Gasparotto). Der Einsatz von Mykorrhizapilzen im Feldanbau hat sich also in verschiedener Hinsicht bewährt. Im folgenden wird darauf eingegangen, inwieweit eine Vermehrung der VAM-Pilze im Feld und eine damit einhergehende Inokulation nicht-besiedelter benachbarter Kulturpflanzen möglich ist.

3.3 Vermehrung von VAM-Inokulum im Feld und Einsatz von "nurse plants" zur Inokulierung nicht-mykorrhizierter Kulturpflanzen

Die Vermehrung von VA-Mykorrhizapilzen ist nur über die Kultivierung geeigneter Wirtspflanzen möglich, da es sich bei diesen Pilzen um obligat biotrophe Symbionten handelt. Die Inokulumsproduktion unter kontrollierten Bedingungen ist im Gewächshaus problemlos möglich. Soll jedoch eine Produktion in großem Maßstab für den Einsatz im Feld durchgeführt werden, stellt sich die Frage, ob nicht eine kostensparende Vermehrung der Pilze vor Ort, also im Feldboden, möglich ist. Für den tropischen Pflanzenbau kommen als schnellwüchsige Wirtspflanzen z.B. Mais und Maniok in Frage. Die Abbildungen 6 bis 8 zeigen, daß die Wurzeln beider Pflanzenarten - unabhängig von einer vorausgehenden Inokulierung - von Mykorrhizapilzen besiedelt wurden und dadurch bereits frisches Pilzinokulum im Boden vorliegt. In welchem Umfang die Besiedelung durch eingebrachtes Inokulum (+M) erfolgte, beziehungsweise auf das im Feldboden vorliegende Pilzmaterial zurückzuführen ist (-M), kann durch mikroskopische Untersuchungen nicht geklärt werden. Aufschluß darüber ließe sich durch die Anwendung eines ELISA-Tests gewinnen, bei dem Antikörper verwendet werden, die spezifisch gegen die eingebrachten Pilze reagieren.

Inwieweit mit der Wurzelbesiedelung von Mais und Maniok eine gleichzeitige Vermehrung des Pilzinokulums einhergeht, sollte über die Bestimmung der Anzahl an VAM-Sporen im Boden überprüft werden. Bei dieser Untersuchung, die auf der Maisanbaufläche erfolgte, wurde zudem der Abstand zur Pflanze berücksichtigt. Die Bodenproben wurden in 10cm beziehungsweise 50cm Entfernung zur Sproßachse entnommen. Allgemein nimmt die Anzahl der Pilzsporen mit der Entfernung zur Pflanze ab (Abb. 10). Eine Erklärung dafür könnte die Ausbreitung des Wurzelsystems sein. Anhand einer Stichprobe wurde festgestellt, daß der größte Teil des Wurzelsystems vom Mais sich innerhalb eines Durchmessers von 50cm befindet. Bei einer Probenahme im Abstand von 50cm zur Pflanze ist also kaum noch Wurzelmaterial vorhanden, an dem Sporen der VAM-Pilze ausgebildet werden könnten. Eine Umkehrung der Verhältnisse, nämlich eine größere Anzahl an Sporen in weiterem Abstand zur Pflanze, findet sich in einigen Fällen, wenn der Mais nicht inokuliert und mit nur 30% der empfohlenen Düngermenge behandelt wurde. Möglicherweise bildet der Mais unter diesen Bedingungen ein größeres Wurzelsystem aus, so daß eine Sporenbildung an den jüngeren Wurzeln in größerem Abstand zur Sproßachse erfolgen kann. Eine detaillierte Untersuchung der Wurzelsysteme vom Mais ist erforderlich, um den vorliegenden Befund abschließend zu erklären.

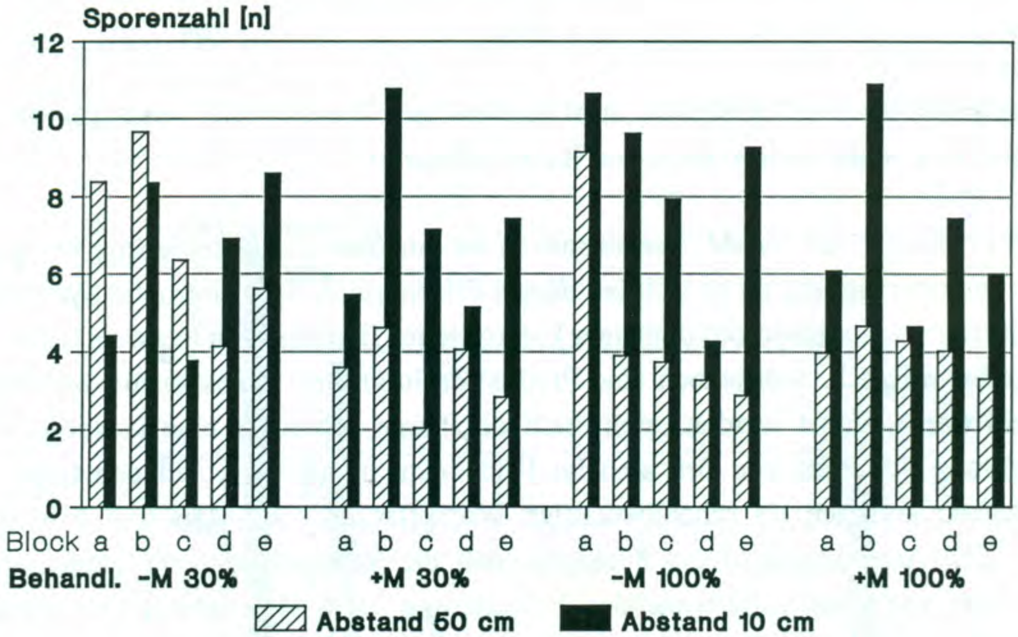

Abb. 10:
Anzahl der VAM-Pilzsporen in Abhängigkeit zur Entfernung von der Maispflanze bei vier unterschiedlichen Behandlungen

Die Sporenzahlen zwischen 2 und 12 Sporen pro cm^3 Boden liegen im gleichen Rahmen wie zum Zeitpunkt der Pflanzung. Eine Vermehrung der Gesamtsporenzahl ist also nicht nachweisbar. Allerdings kann trotzdem eine Inokulumsvermehrung stattgefunden haben, da nicht nur Sporen, sondern auch Pilzhyphen beziehungsweise infiziertes Wurzelmaterial als Infektionseinheiten fungieren.

Eine eindeutige Vermehrung von VAM-Sporen konnte allerdings für Pilze der Gattung *Scutellospora* festgestellt werden. Während zum Zeitpunkt der Pflanzung nur 20% der Bodenproben Sporen dieser Pilzgattung enthielten (40% der Proben aus Parzellen mit späterem Maisanbau), konnten in der Phase des Maisanbaus in 58% der Proben Sporen von Scutellospora nachgewiesen werden. Der Anteil der *Scutellospora*-Sporen an der Gesamtsporenzahl der jeweiligen Proben aus der Maisanbaufläche liegt zwischen 1 und 13%, während er zum Zeitpunkt der Pflanzung maximal 3% ausmachte. Durch die Vermehrung des Anteils der Sporen von Scutellospora an der Gesamtsporenzahl kommt es gleichzeitig zu einer Verschiebung des zahlenmäßigen Verhältnisses der Sporen unterschiedlicher Pilzgattungen bzw. -arten. Diese Veränderung, sofern es sich dabei nicht nur um eine periodische Schwankung handelt, kann durchaus auf die zukünftige Entwicklung der Kulturpflanzen Einfluß nehmen und ebenso auf die Stabilität der Plantage.

Als Nebeneffekt stellte sich heraus, daß die mit Mykorrhizapilzen inokulierten Maispflanzen einen etwas höheren Ertrag liefern als nicht-inokulierte Pflanzen derselben Düngungsstufe (Tab. 3; siehe auch Bericht Macedo). Allerdings wird durch den Einsatz der Mykorrhizapilze bei 30%iger Düngungsstufe nicht die Höhe des Ertrages der Variante mit 100% Düngung erzielt. Da die nicht-inokulierten Kontrollpflanzen ebenfalls von VAM-Pilzen besiedelt wurden, aber trotzdem einen niedrigeren Ertrag aufwiesen als die inokulierten Pflanzen, muß man davon ausgehen, daß dieser Unterschied auf die applizierten Pilze zurückgeht, die offenbar hinsichtlich der Ertragserhöhung effektiver sind als die autochtonen VA-Mykorrhizapilze.

Tab. 3:
Maisertrag in Abhängigkeit von Düngung und Inokulation mit VA-Mykorrhizapilzen

Behandlung	Ertrag [kg/ha]	Ertrag [%]
-M 30%	388 ± 105	70
+M 30%	424 ± 89	76
-M 100%	557 ± 202	100
+M 100%	620 ± 110	111

Mit der Besiedelung der Wurzeln von Maniok und Mais können diese Pflanzen als "nurse plants" dienen, d.h., ausgehend von den mykorrhizierten Wurzelsystemen können andere nicht-mykorrhizierte Kulturpflanzen besiedelt werden. Welchen Beitrag Mais und Maniok tatsächlich zur indirekten Inokulation nicht-mykorrhizierter Kulturpflanzen leisten, wurde beispielhaft anhand der Wurzelbesiedelung von Citrus untersucht. Die Citruspflanzen waren bei Einbringung ins Feld nicht mykorrhiziert. Bei der Pflanzung wurden 50% der Pflanzen im Mischkulturanbau inokuliert. Die andere Hälfte sowie alle Citruspflanzen der Monokultur wurden nicht mit Mykorrhizapilzen behandelt. In der Polykultur werden die Citruspflanzen von Mais und Maniok bzw. von Bohnen und Maniok flankiert. Zur Auswertung wurden nur die Citruspflanzen herangezogen, die in Nachbarschaft zu Mais und Maniok kultiviert werden.

Wie bereits ausgeführt, resultiert aus der Inokulierung von Citrus in der Polykultur trotz der ebenfalls inokulierten "nurse plants", Mais und Maniok, nicht ein wesentlich höherer Wurzelbesiedelungsgrad im Vergleich zu den Kontrollpflanzen, was auf das im Feld vorhandene Inokulum zurückzuführen ist. Der Einfluß der "nurse plants" wird aber deutlich, wenn man die Daten zur Wurzelbesiedelung der Pflanzen aus dem Mischkulturanbau denen aus der Monokultur gegenüberstellt. Die Citruspflanzen der Mischkultur sind deutlich stärker besiedelt als die der Monokulturen (Abb. 11). Über den Mais und den Maniok muß also eine Vermehrung des im Feldboden vorhandenen bzw. des applizierten Inokulums sowie eine anschließende Besiedelung der Citruspflanzen durch die VAM-Pilze erfolgt sein. Ohne den Anbau der "nurse plants" geht die Mykorrhizierung der Citruspflanzen offenbar langsamer voran oder erreicht womöglich in keinem Fall das Ausmaß wie im Mischkulturanbau. Dieser Befund stützt die Vermutung, daß die spontane Vegetation, die in den Monokulturen als Bodenbedeckung zugelassen wird, nicht für die Vermehrung und Verbreitung der VAM-Pilze geeignet ist (s.o.). Ob dies nur unter den Bedingungen des Plantagenmanagments gilt oder auch in älteren, ungestörten Sekundärwaldflächen zutrifft, muß in Zusatzexperimenten geklärt werden.

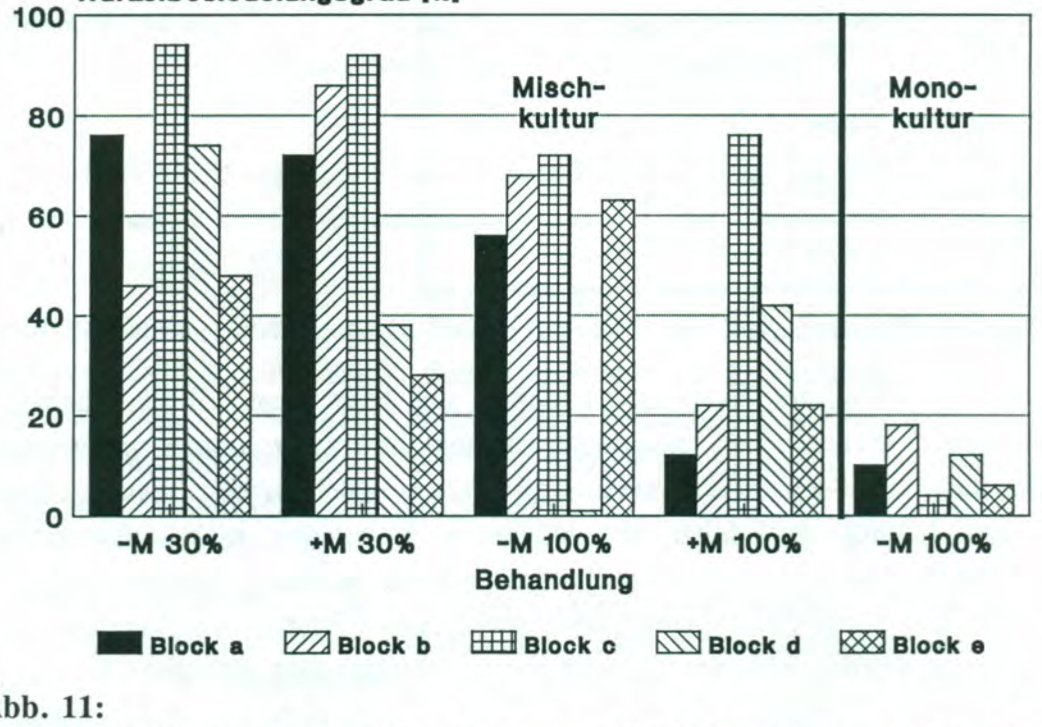

Abb. 11:
Wurzelbesiedlungsgrade der Citruspflanzen in Mischkultursystemen im Vergleich zu den Monokulturen (getrennt ausgewertet nach Blöcken); Probenahme: neun Monate nach Pflanzung (Legende s. Abb. 5)

4 Diskussion

Generell ist es schwierig, Resultate aus kontrollierten Laborexperimenten oder Gewächshausversuchen auch unter Freilandbedingungen zu erzielen. In Bezug auf den Einsatz von VA-Mykorrhizapilzen im Plantagenbau konnten mit Hilfe des 19ha-Experiments jedoch zahlreiche der positiven Eigenschaften einer Mykorrhizasymbiose bestätigt werden. So ist das Wachstum mykorrhizierter Pflanzen gefördert, der Befall durch phytopathogene Pilze vermindert und die geringeren Auspflanzverluste von VAM-inokulierten Pflanzen weisen auf die erhöhte Toleranz gegenüber Streßsituationen hin. Der Einsatz von VA-Mykorrhizapilzen in der Anfangsphase der Pflanzung hat sich damit bereits bewährt.

Betrachtet man nun den Aspekt der zeitlichen Stabilität einer Plantage unter Berücksichtigung der VAM, so muß man sich die Frage stellen, ob die eingebrachten Mykorrhizapilze sich auf Dauer gegen die Konkurrenz der autochtonen Mykorrhizapilze durchsetzen können. Insbesondere muß dabei bedacht werden, daß ein Anbau von Wirtspflanzen der VAM, die für deren Vermehrung in Betracht kommen (Maniok und Mais), nur zeitlich begrenzt möglich ist. Damit bleiben als Wirtspflanzen für die VAM nur die perennierenden Kulturpflanzen sowie Pflanzen der Sekundärvegetation. Die vorgestellten Befunde weisen darauf hin, daß gerade die Pflanzen der Sekundärvegetation, die in großer Anzahl auf der Plantage vorhanden sind, nicht besonders als Wirtspflanzen für die VAM geeignet sind. Um den Mykorrhizapilzen einen guten Symbiosepartner zu bieten, könnten weiterreichende Studien vorgenommen werden, die darauf abzielen, eine oder mehrere VAM-Wirtspflanzen(n) innerhalb der spontanen Vegetation zu finden und die Möglichkeit ihrer Förderung oder Einbringung in die Plantage zu prüfen.

Bereits jetzt muß man davon ausgehen, daß eine Veränderung in bezug auf Quantität und qualitative Zusammensetzung der Mykorrhizapilze auf der Versuchsfläche stattgefunden hat. Vor der Brandrodung der Fläche lag die durchschnittliche Anzahl an VAM-Pilzsporen bei 12 Sporen/cm^3 Boden (siehe Jahresbericht 1992). Zum Zeitpunkt der Pflanzung, sechs Monate später, belief sich dieser Wert auf nur noch 6 Sporen/cm^3 Boden. Abgenommen hat dabei offenbar in erster Linie die Anzahl von Sporen der Klasse *Glomus* b. Welche Bedeutung dies für die Plantage und ihre Stabilität hat, ist noch nicht abzusehen und nur durch langfristige Studien zu klären.

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Nodulação em *Pueraria phaseoloides* em amostras de solo do experimento "Recuperação de Áreas Abandonadas"

L.A. Oliveira & F.W. Moreira

Zusammenfassung:

Vorkommen von Knöllchen bei Pueraria phaseoloides in Bodenproben des Experiments "Rekultivierung von Brachflächen"

Bei der Rekultivierung ehemals landwirtschaftlich genutzter Flächen der terra firme im Amazonasgebiet spielt die Symbiose von Leguminosen und N_2-fixierenden Bakterien für die Einbringung von Stickstoff in den Boden eine wichtige Rolle, da diese Böden im allgemeinen ein Defizit an Stickstoff aufweisen. Aus diesem Grund wurde untersucht, ob auf der Experimentalfläche des CPAA Rhizobien vorkommen und inwieweit sie eine effektive Symbiose mit der Leguminose Pueraria phaseoloides eingehen, die in der Plantage mit großen Mengenanteilen vorhanden ist. Zu diesem Zweck wurden aus dem Feld Bodenproben entnommen. Im Gewächshaus wurde auf diesen Proben Pueraria kultiviert. Die Analyse der Wurzeln nach viermonatiger Kulturdauer ergab, daß nur sehr wenige Knöllchen ausgebildet wurden. Selbst die maximal erreichte Anzahl an Knöllchen - 34 Knöllchen an acht Pflanzen - ist für einen effizienten Stickstoffeintrag unzureichend.

Darüberhinaus war zu beobachten, daß ein großer Teil der Puerariapflanzen im Gewächshausversuch abstarb. Dies wird auf pathogene Mikroorganismen im Boden zurückgeführt, die die Samenkeimung und die weitere Entwicklung der Pflanzen beeinträchtigen.

1 Introdução

As leguminosas têm papel muito importante na recuperação de áreas utilizadas pela agricultura de terra firme da Amazônia. Cerca de 90% destes solos são deficientes de nitrogênio, fazendo com que plantas com potencial de fixação do nitrogênio, como as leguminosas, sejam utilizadas para aumentar o teor deste elemento no solo. No entanto, uma série de fatores bióticos e abióticos podem interferir no processo simbiótico planta-rhizobio, impedindo a expressão adequada da fixação do nitrogênio. A puerária é muito utilizada como planta de cobertura em cultivos de terra firme da região, tornando-se necessário testar se esta espécie nodula adequadamente na área experimental do projeto. Um ensaio preliminar pode indicar se esta nodulação ocorre e se está sendo efetiva, a ponto de aumentar o teor de nitrogênio no solo.

2 Material e métodos

Foram coletadas amostras de solos de 30 das parcelas do projeto Recuperação, situado na EMBRAPA/CPAA. Cada amostra consistiu de 2.0 kg de solo, coletando-se três em cada parcela do experimento, como repetições. Coletaram-se, também, três amostras de solo de uma área de capoeira contígua ao experimento, para servir de controle. As amostras foram analisadas quimicamente e colocadas em vasos, instalando-se assim um experimento em casa-de-vegetação. Foram colocadas sete sementes em cada vaso, deixando-se três plantas em cada um para posterior avaliação de nodulação e desenvolvimento. As plantas foram colhidas quatro meses após o plantio, sendo analisados os seus pesos e o peso e o número de nódulos.

3 Resultados parciais

Os resultados obtidos quanto à presença ou ausência de nodulação encontram-se na Tabela 1. Observa-se que, do total de 31 parcelas, 21 apresentaram plantas com nodulação; enquanto que, em dez das parcelas, algum fator (biológico ou não) impediu as plantas de nodularem. Como não foi utilizado inoculante, é possível que esta falha de nodulação possa ser devido à ausência de rhizóbio na área. A presença de nódulos não significa eficácia dos mesmos, pois o número máximo de nódulos encontrado foi de 34 em oito plantas na parcela e6, sendo este um número muito baixo e insuficiente para proporcionar uma fixação biológica eficiente de nitrogênio.

Isto implica que, na área experimental, a puerária vai agir como planta que retira o nitrogênio do solo, não aumenta nada o balanço deste elemento no solo. São necessários mais experimentos para se determinar quais os fatores do solo que estão afetando a ocorrência e eficiência da nodulação.

Por outro lado, houve uma porcentagem elevada de morte das plantas nos vasos, pois foram colocadas sete sementes em cada um, visando deixar apenas três plantas por vaso. Por este cálculo, deveria haver nove plantas por parcela, o que não ocorreu. Algumas parcelas, como a3, b12 e b16, apresentaram apenas duas plantas, indicanco que das 21 sementes colocadas no solo, apenas duas desenvolveram-se. Estes dados são um indicativo de que algum microorganismo patogênico encontra-se no solo, afetando a germinação e o desenvolvimento das plântulas. Assim, para que a puerária possa contribuir para a proteção do solo e aumentar o teor de nitrogênio no solo, os fatores edáficos que afetam a sua germinação, desenvolvimento e nodulação devem ser eliminados.

Tabela 1:

Nodulação em *Puerária phaseoloides* plantada em solos das parcelas do experimento "Recuperação de áreas abandonadas"

Parcelas	Presença de nodulação (n° de nódulos/n° de plantas)
a1	1/3
a3	6/2
a8	0/7
a10	0/2
a12	0/4
a16	2/8
b1	2/8
b3	6/9
b10	2/5
b12	0/2
b13	3/5
b14	2/4
b16	0/2
c2	1/9
c5	0/9
c10	14/9
c13	3/9
c15	4/6
c16	6/7
d2	5/7
d5	2/3
d9	0/4
d11	0/1
d15	5/7
d18	5/5
e2	8/9
e6	34/8
e7	19/6
e9	6/9
e12	0/3
e15	0/4
Capoeira	0/9

Micorrizas vesículo-arbusculares em plantas do experimento "Recuperação de Áreas Abandonadas"

E.M. Figueiredo & L.A. Oliveira

Zusammenfassung:

Vorkommen von vesiculär-arbuskulärer Mykorrhiza in Pflanzen des Experiments "Rekultivierung von Brachflächen"

Eine Mykorrhizasymbiose wirkt sich im allgemeinen vorteilhaft auf die Gesundheit und das Wachstum der Wirtspflanzen aus. Daher ist es von Bedeutung zu klären, welches Potential an Mykorrhizapilz-Inokulum auf der Experimentalfläche vorliegt und inwieweit dieses Potential zeitlichen Schwankungen unterliegt. Zu diesem Zweck wurden die Wurzeln verschiedener Pflanzen der Sekundärvegetation zu zwei Zeitpunkten auf Besiedelung durch vesikulär-arbuskuläre Mykorrhizapilze hin untersucht. In jedem Fall wurden zum ersten Zeitpunkt hohe Besiedelungsgrade - meist im Bereich von 90% - nachgewiesen. Zum zweiten Untersuchungstermin waren die Werte häufig niedriger. Dies zeigt, daß tatsächlich mit jahreszeitlichen Schwankungen gerechnet werden muß. Durch zukünftige Untersuchungen wird sich eine Aussage darüber treffen lassen, welche der analysierten Pflanzenarten am besten als Wirtspflanze für die Mykorrhizapilze und damit auch als Inokulumsquelle geegnet ist.

Die durchgeführten Studien sind als begleitende Untersuchungen zu den Arbeiten von Feldmann und Idczak gedacht.

1 Introdução

As micorrizas vesículo-arbusculares podem ser importantes para a nutrição das plantas nos solos pobres e ácidos da terra firme da Amazônia. Estes solos são deficientes da maioria dos nutrientes e as plantas com maior capacidade de absorção destes elementos do solo podem ter um melhor desenvolvimento nestas condições. A maioria das plantas regionais apresenta este tipo de simbiose, mas faltam estudos mais detalhados de como esta associação se comporta durante o ano, bem como as plantas que podem manter um estoque ativo no solo, antes de se instalar espécies de importância econômica. O estudo foi feito para complementar os trabalhos de Idczak e Feldmann sobre aplicação e abundância de fungos micorrízicos na área experimental.

2 Material e métodos

Foram feitas coletas periódicas de raízes de várias espécies de ocorrência natural na área experimental, com o objetivo de verificar quais delas mantêm estoque ativo de micorrízas VA até que as culturas principais desenvolvam-se adequadamente e possam beneficiar-se desta simbiose. Foram feitas coletas com cinco repetições para cada espécies, em cada época.

3 Resultados parciais

A Tabela 1 apresenta os dados parciais, compreendendo duas das coletas feitas até o momento. Os dados restantes estão ainda em fase de organização e análise.

Observa-se que não foi possível encontrar arbúsculos nas amostras de raízes nas duas coletas feitas. No entanto, os índices de infecções foram elevados, chegando a 100% das raízes. Com exceção das duas últimas espécies (*Piper aduncum* e *Irlbachia alata*), os índices de infecções nas raízes coletadas em 17/08/93 foram maiores do que nas coletadas em 18/10. Em *Piper aduncum* ocorreu o inverso, enquanto que em *Irlbachia alata*, em ambas as coletas as infecções por MVA foram elevadas.

Tabela 1:
Micorrizas VA em raízes das plantas do experimento "Recuperação de áreas abandonadas"

Plantas	Infecções [%] 1ª Col.	Infecções [%] 2ª Col.	Arbúsculos [%] 1ª Col.	Arbúsculos [%] 2ª Col.
Vismia guianensis	93	61	0	0
Pueraria phaseoloides	85	65	0	0
Homolepis aturensis	98	71	0	0
Belucia imperialis	96	73	0	0
B. grossularioides	95	85	0	0
Cecropia sp.	100	94	0	0
Piper aduncum	50	96	0	0
Irlbachia alata	96	100	0	0

Coletas: 1ª (17/08/93) - 2ª (18/10/93)

As diferenças de infecções de sete das oito espécies nas duas épocas de coletas, indica que as MVA podem variar suas ocorrências durante o ano, o que se confirmará com os dados das próximas coletas. Assim, pode-se escolher aquelas espécies que são as melhores mantenedoras dos estoques de micorrizas até que as culturas principais e de importância econômica desenvolvam-se adequadamente e possam beneficiar-se também desta associação.

Microorganismos solubilizadores de fosfatos, em raízes de plantas do experimento "Recuperação de Áreas Abandonadas"

N.A.F. Farias & L.A. Oliveira

Zusammenfassung:

Vorkommen von Phosphat solubilisierenden Mikroorganismen an Wurzeln von Pflanzen des Experiments "Rekultivierung von Brachflächen"

In den Böden der "Terra Firme" Amazoniens ist Phosphat generell der limitierende Faktor für das Pflanzenwachstum. Phosphat-solubilisierende Mikroorganismen im Boden könnten dazu beitragen, die Nährstoffsituation für die Pflanzen zu verbessern. Untersuchungen zum Vokommen dieser Mikroorganismen in der Rhizosphäre von Pflanzen der Sekundärvegetation auf der Experimentalfläche zeigen, daß die Häufigkeit ihres Vorkommens jahreszeitlichen Schwankungen unterliegt. In der Trockenzeit (Zeitpunkt der Untersuchung: August) ist die Anzahl Phosphat-solubilisierender Mikroorganismen größer als zu Beginn der Regenzeit (Oktober, November). Der größte Teil dieser Mikroorganismen sind Bakterien, in einigen Fällen wurden Phosphat--solubilisierende Pilze nachgewiesen. Es bietet sich die Möglichkeit, die besten Isolate der Phosphat-solubilisierenden Mikroorganismen für einen zukünftigen Einsatz im Anbau ökonomisch wichtiger Kulturen zu selektionieren.

1 Introdução

Os microorganismos solubilizadores de fosfato podem ser de grande importância para a nutrição das plantas nos solos ácidos e de baixa fertilidade da terra firme amazônica. Estes solos são bastante deficientes em fósforo, tornando-se este elemento o principal fator limitante para o desenvolvimento adequado das plantas de importância econômica. As presenças e manutenção desta população de microorganismos no solo pode auxiliar melhor adaptação das plantas às condições edáficas locais, permitindo melhor desenvolvimento e produtividade das mesmas. Poucos estudos foram realizados até o momento com estes microorganismos. Nada foi feito, por exemplo, com relação à variação sazonal dos mesmos nas rizosferas das plantas, sendo este o objetivo do presente estudo.

2 Material e métodos

As raízes coletadas para as avaliações de ocorrência de MVA foram utilizadas para o presente estudo. Elas foram levadas para o laboratório do INPA, onde foram cortadas e coletadas em placas de Petri contendo meio de cultura apropriado para avaliar as ocorrências de solubilizadores de fosfatos. Os resultados obtidos foram expressados em porcentagens de ocorrências.

3 Resultados preliminares

A Tabela 1 mostra os dados das ocorrências de microorganismos solubilizadores de fosfato encontrados nas rizosferas das oito espécies estudadas no experimento de Recuperação de áreas marginais.

Os resultados com os microorganismos solubilizadores de fosfatos foram semelhantes aos obtidos com micorrizas, pois a primeira coleta (17/08/93) foi a que apresentou os maiores números de solubilizadores de fosfato. Nas outras duas coletas os números foram muito menores, indicando uma variação sazonal bastante característica. Com relação às espécies de plantas, as três com maiores porcentagens de solubilizadores de fosfatos foram, por ordem, a gramínea (em fase de identificação), a puerária e a *Vismia guianensis*. Com relação aos microorganismos solubilizadores de fosfato, predominou a ocorrência de bactérias, sendo bem menor a de fungos.

A continuidade deste estudo poderá dar informações de como esta variação sazonal ocorre durante todo o ano e quais os fatores edáfico-climáticos que são responsáveis por esta variação. Permitirá, também, selecionar os melhores solubilizadores de fosfatos dentre os isolados para usos futuros em plantas de importância econômia.

Tabela 1:

Microorganismos solubilizadores de fosfato encontrados nas raízes das plantas do experimento "Recuperação de áreas abandonadas"

	Bactérias [%]			Fungos [%]		
Plantas	1ªCol.	2ªCol.	3ªCol.	1ªCol.	2ªCol.	3ªCol.
Vismia guianensis	29	7	3	9	0	3
Pueraria phas'oides	32	2	0	5	0	0
Homolepis aturensis	52	12	2	14	1	0
Belucia imperialis	12	3	2	22	0	0
B. grossolarioides	11	1	1	10	0	0
Cecropia sp.	11	5	5	2	0	0
Piper aduncum	5	3	1	1	0	0
Irlbachia alata	10	0	0	0	0	0

Coletas: 1ª (17/08/93) - 2ª (18/10/93) - 3ª (25/11/93).

Studies on root structure of some useful plants and on medicinal plants occuring in the secondary vegetation of an experimental area near Manaus-AM[1]

Karsten Voß

1 Introduction

The studies were carried out in an experimental area of the EMBRAPA/CPAA north of Manaus-AM and can be classified into two main fields of interest:

1. root systems, rooted areas and soil horizons (description of root systems of selected useful plants in the experimental area; studies on soil layers, layers of organic material and rooted areas in the test area, in an adjacent secondary forest and in a primary forest margin;

2. medicinal plants: which plant species of the secondary vegetation found before and one year after clearing of the area are known to be medicinal plants?

2 Root systems

The root systems of selected useful plants inoculated with mycorrhiza fungus spores and plants not inoculated, were analysed (*Bixa orellana, Bertholecia excelsior, Theobroma grandiflora* and *Hevea brasiliensis*). The root systems of one individual of each species and with / without inoculation were dug out up to 55 cm depth, to explore the spatial extension and specific macroscopic traits of the roots, preferably of the rootlet area. The excavations were conveyed with simple tools. So it was only possible to focus on one half of the root system to get an impression of the root structure. The studies were documented by hand drawings, with specification of root lengths and rooted areas. A preliminary evaluation indicate that differences between inoculated test plants and those not inoculated do not exist.

The studies on root systems, which were carried out for the first time in the area under study, give raise to the following questions:

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[1] Short report of the studies carried out under the SHIFT-project "Recultivation of abandoned areas ..." (ENV-23) from 10 October - 27 Dezember 1993

- Would a "nurse plant effect" occur (spreading of mycorrhiza from mainly short living plant species to perennials), considering the distances between the rootlet areas of neighbouring plants?

- Which conclusions relating to nutrient uptake are to be drawn from the results of distribution and density of the rootlets in the organic layer and in the soil?

- Are there differences in the root structure between useful plants in mixed culture and in monoculture plantations?

- Is it possible to identify roots of the different useful plants under study, based on specific and macroscopic recognizable root traits?

Soil excavations in the plantation of the test area, in a 10 year old secondary forest and in an adjacent primary forest margin were carried out to accumulate knowledge about the extent of rootlets growing through the soil and the organic layer. The soil description involved drawings of soil sections and measurements of the soil layer thicknesses. Soil samples were taken from the upper 20 cm and from 50 to 55 cm depth. The contents of organic material (each sample of 1 g) and of the elements P, K, Ca, Mg and Al (each sample of 10 g) were determined.

The comparative studies mentioned above were undertaken to get or improve the knowledge of

- the importance of the thickness of the organic layer for plant nutrition,

- the effect of structural traits of the organic layer and the soil on structure and function of the root systems,

- the disribution and amount of organic material and key nutrients in different soil layers, and the availability of these nutrients for the plant and uptake by the rootlets.

2 Medicinal plants

Based on existing plant lists from an analysis of vegetation in the test area and adjacent areas (before and one year after planting), plant species of officinal use - as known from literature - were identified. Scientific names, common names, a short botanical description, those parts of the plant body which are used officinally, and form and field of drug application were listed in a table. More than 45 plant species of officinal use which grow or grew on the experimental area could be recorded.

Based on the inventory of medicinal plants carried out, studies on the following subjects could be made:

- disturbance tolerators among medicinal plants which would survive in a mixed culture plantation of the experiment;
- prediction for medicinal plant species of economic interest in the near future;
- officinal plant species which can be grown as crops in a mixed culture plantation.

Acknowledgement

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Incidência de doenças nos sistemas de monocultivo e de policultivo

L. Gasparotto & M.I.P.M. Lima

Zusammenfassung:

Auftreten von Krankheiten in den Monokultur- und Mischkultursystemen
Die klimatischen Verhältnisse Amazoniens begünstigen Pflanzenkrankheiten. Dazu gehören Blattkrankeiten beim Kautschuk, für die Pilzerreger verantwortlich sind. Lösungsansätze für diese Probleme bestehen in der Züchtung und im Einsatz resistenter oder wenig anfälliger Clone und Sorten und im Anbau der gefährdeten Nutzpflanzenarten in Mischkultursystemen. In der SHIFT-Mischkulturplantage erfolgen alle zwei Monate Erhebungen über den Gesundheitszustand der Nutzpflanzen. Beim Kautschuk mußte im August 1993 gegen die Pilzerreger Microcyclus ulei und Thanatephorus cucumis ein Blattfungizid eingesetzt werden. Davon abgesehen, gab es bis Dezember 1993 nur beim Maniok Probleme. Die Pflanzenkrankheiten nehmen in allen Kulturen zu, besonders in den Monokulturen. Dabei gibt es keine Unterschiede zwischen den Behandlungen. Der Verlauf der südamerikanischen Blattfallkrankheit beim Kautschuk ist für die Monate Juli bis Dezember 1993 in einem Balkendiagramm dargestellt.

1 Introdução

As condições climáticas na região Amazônica são extremamentee favoráveis à ocorrência de doenças em plantas. A história registra que várias tentativas de monocultivo na região têm fracassado, em grande parte, devido a alta incidência de doenças. Como exemplo, os plantios de seringueira efetuados pela Companhia Ford em Belterra e Fordlândia-PA, na década de 30 (Holliday 1970), e cerca de 75000 ha de seringais implantados em 1970/1980 (Gasparotto et al. 1990). Os cacauais implantados em Rondônia, a partir de 1970, têm sido afetados pela vassoura de bruxa (*Crinipellis perniciosa*). Essa mesma doença tem inviabilizado os plantios de cupuaçuzeiro. Podemos citar, ainda, a mandioca estabelecida nas várzeas, onde o *Phytophthora* spp. tem sido o principal problema; bem como o fracasso da pimenta-do-reino, dizimada por *Fusarium oxysporum* f. sp. *piperis*, no Pará.

Sabe-se que há diferenças quanto à incidência de doenças em monocultivos e em sistemas de policultivo. Porém, as informações, na maioria das vezes, são inexistentes ou não conclusivas. A seringueira e o cupuaçuzeiro, em seu habitat natural, intercalamse com outras espécies vegetais não afetadas por suas doenças, dificultando a disseminação e evitando a ocorrência de uma epidemia.

A solução real para os problemas agrícolas na região Amazônica poderá ser encontrada em sistemas de policultivo com plantas resistentes e perenes. Estes sistemas permitem estabelecer condições semelhantes às existentes na floresta primária, onde as espécies não hospedeiras dos patógenes servem de barreira para impedir a dispersão dos esporos por respingos de chuva e pelo vento e, consequentemente, a incidência de doenças, minimizando os riscos de insucesso. Deste modo, o presente trabalho objetiva estudar a incidência e o progresso de doenças nas espécies de plantas estabelecidas nos diferentes sistemas de monocultivo e de policultivo, componentes do projeto "Recuperaçao de áreas degradadas, através de sistemas de policultivo".

2 Material e métodos

Em mogno, andiroba, paricá, castanha-do-Brasil, coco, citrus, urucum, mamoeiro e mandioca, são feitos levantamentos de incidência de doenças à intervalos de 2 meses. No cupuaçuzeiro as vistorias para contagem dos lançamentos com vassoura-de-bruxa são a cada 2 meses. No milho, a avaliação de doença foi feita no período de enchimento das espigas.

Na seringueira são marcados, mensalmente, lançamentos jovens e avaliada a severidade das doenças. Vale ressaltar que, nas plantas de seringueira, vem sendo aplicado o fungicida Triadimenol (Bayfidan a 0,12%), desde agosto de 1993, para proteger os lançamentos contra *Microcyclus ulei* e *Thanatephorus cucumeris*, a fim de permitir que as plantas atinjam a altura suficiente para proceder a enxertia de copa. Assim, os resultados de avaliação de severidade das doenças em seringueira ficam até certo ponto prejudicados.

3 Resultados e discussão

Até dezembro de 1993, não havia incidência de doenças em todas as culturas, exceto em seringueira e mandioca.

Pelo fato de as plantas, dentro de cada sistema, não terem atingido uma altura suficiente para formar barreiras impedindo a disseminação dos patógenos, semelhante à floresta natural, optou-se por comparar a severidade das doenças da seringueira, considerando-se como tratamento as combinações de adubações com inoculações do fungo micorrízico *Glomus etunicatus* e a monocultura (Fig. 1). A disparidade de incidência das doenças no tratamento 30%/-mic, no mês de setembro, bem como a inconstância dos dados obtidos para cada tratamento, provavelmente, verificaram-se devido ao número variado de plantas que encontraram-se em condições de serem avaliadas. Nos meses de setembro e outubro, houve redução drástica na severidade das doenças, devido ao controle químico efetuado. Em novembro e dezembro, apesar de continuar com o controle químico, a severidade aumentou provavelmente em função do período chuvoso que reduz a eficiência do controle.

A incidência das doenças em todas as culturas tende a aumentar, principalmente nos sistemas de monocultivo, à medida em que as plantas apresentarem maior disponibilidade de tecido suscetível. No caso da seringueira, a partir do quarto ano. Assim, diferenças na intensidade de ataque das doenças entre os diferentes sistemas, provavelmente serão detectadas a partir do terceiro ou quarto ano após a instalação do experimento. - Na mandioca ocorreu baixa incidência de *Xanthomonas campestris* p.v *manihotis*, em agosto de 1993. Segundo o Dr. Losano do CIAT/Colômbia, a doença só se manifesta com alta intensidade em regiões com temperaturas amenas.

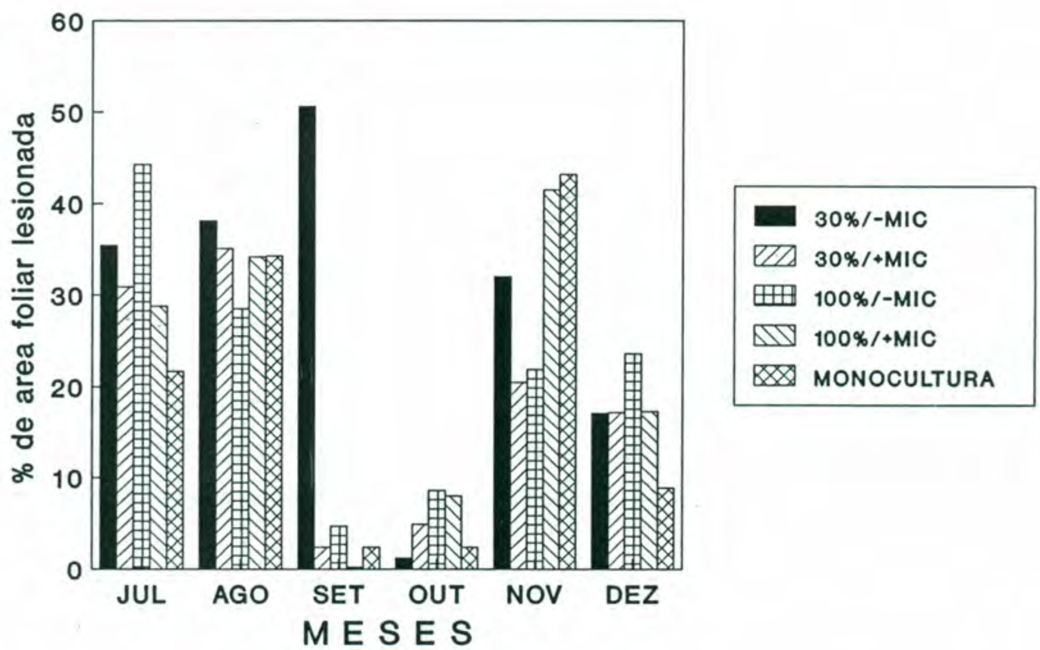

Figura 1:

Progresso da mancha areolada e do mal-das-folhas em seringueiras submetidas à adubação completa (100%) e parcial (30%), associadas ao fungo micorrízico (+mic.) ou não (-mic.).

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Observações de insetos na área experimental e adjacentes nos diferentes ambientes

Ana M.S.R. Pamplona

Zusammenfassung:

Beobachtungen zur Insektenfauna auf der Experimentalfläche und in angrenzenden Ökotopen

Der Insektenbefall der verschiedenen Nutzpflanzen wurde beobachtet und dokumentiert, ggf. wurden Bekämpfungsmaßnahmen eingeleitet. Außerdem wurden in den verschiedenen Pflanzsystemen und Behandlungen mit dem Netz und durch Absammeln Insekten zur späteren Bestimmung gefangen. Zusätzlich wurden Lichtfänge auf der Experimentalfläche, im Sekundär- und Primärwald-Rand zu unterschiedlichen Zeiten durchgeführt. Die Tag- und Nachtfänge sollen vor allem zur späteren Abschätzung potentialer Gefahren von Insekten-Kalamitäten dienen, jedoch auch zum besseren Verständnis der Lebensräume Primärwaldrand - Sekundärwald - Brachfläche - Plantage beitragen. Auf die Populationsentwicklung einer bis 12 cm groß werdenden Schmetterlingsraupe (Erynnis ello) wird besonders eingegangen, weil die Raupe schon in kleinen Individuenzahlen am Maniok in wenigen Stunden große Schäden anrichten kann.

1 Introdução

A vasta abrangência territorial da Amazônia é um fator que dificulta, um melhor conhecimento da região. A fauna e a flora exuberante pouco conhecidas têm impedido o sucesso de muitas culturas, como exemplo seringueira, cujo estabelecimento foi frustado, devido a ocorrência de doenças e pragas. Segundo Fazolin (1991), devido o desequilíbrio ecológico ocasionado pelo monocultivo tem aumentado os prejuízos causado por diversas espécies de insetos a cultura de seringueira.

Matioli (1988) chama a atenção para o uso de tecnologia dissociada da realidade, a exemplo do uso abusivo de produtos fitossanitários, sem associá-los a outras medidas complementares, amenizando o impacto sobre o ecossistema.

Na agricultura, o controle integrado é imprescindível, mas para adotá-lo é necessário conhecer o problema, começando por identificar o agente causal. No caso de inseto, avaliando-se a entomofauna e a pressão sobre as culturas existentes. Isso é possível com armadilha luminosa, dispositivo para atração e captura de insetos fototrópicos positivos de atividades noturnas.

O presente trabalho tem por objetivo avaliar as pragas das culturas dos consórcios, bem como a entomofauna das áreas circunvizinhas ao projeto e sua influência sobre o mesmo.

2 Metodologia

A coleta dos dados foi feita no plantio e nas adjacências da área dos consórcios (floresta e capoeira, Figura 1), utilizando os seguintes métodos de captura:

1. Coletas, à noite, com armadilha luminosa tipo "Luis de Queiroz", instalada em três tipos de ambientes (parcelas na área de consórcio, capoeira e floresta primária),
2. Coletas de insetos, durante o dia com varredura (rede entomológica), coletas manuais e observações
    - em plantas de consórcio (sistemas 1, 2, 3 e 4),
    - em plantas de monocultivo (sistemas 6, 7, 8, 9)
    - em plantas de pousio (sistema 4[1] e 5)

(1) Coleta a noite (armadilha luminosa)

- Área dos consórcios: instalada nas parcelas b11 e e14 e no "ponto 1", próximo ao experimento composto por maracujá, mamão, mandioca e milho, a uma altura de 1,50m do solo. Esta altura aumentará conforme o crescimento das plantas;
- Capoeira: as armadilhas estão instaladas a 50m da entrada, em frente ao bloco a4, às alturas de 1,5 m e 7,5 m;
- Mata primária: a cerca de 50m no interior da floresta, com a entrada em frente as parcelas do bloco C, às alturas de 1,5, 7,5 e 15 m.

As coletas são mensais, obedecendo o período de domínio da lua nova. Calendário de coleta:

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[1] vegetação espontânea entre as linhas

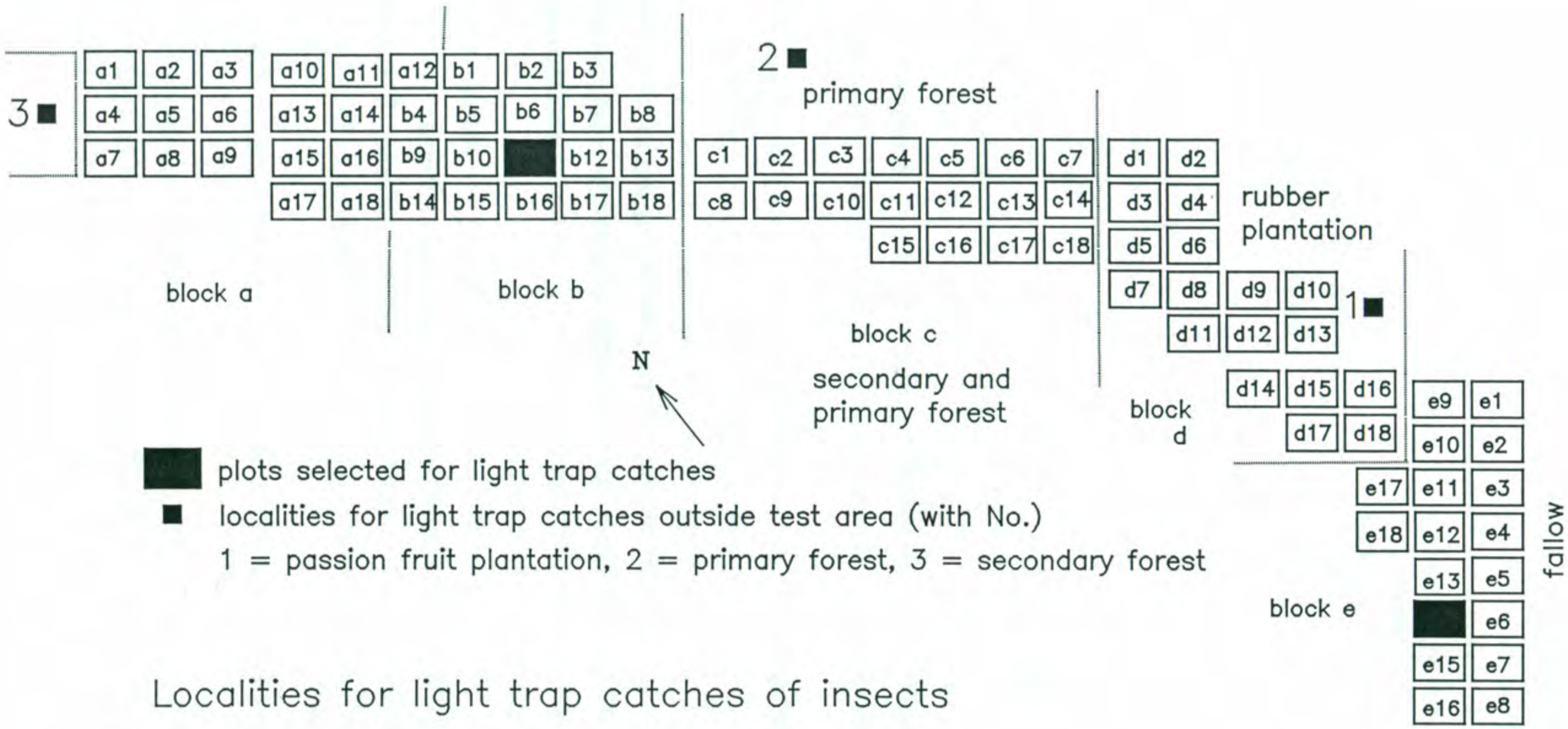

Figura 1:
Locais das armadilhas luminosas na área experimental e áreas adjacentes para coleta de insetos

Dias principais (Fase de Domínio)
21 de maio (19 a 23 de maio)
19 de junho (17 a 21 de junho)
19 de julho (17 a 21 de julho)
17 de agosto (15 a 19 de agosto)
16 de setembro (14 a 18 de setembro)
15 de outubro (13 a 17 de outubro)
13 de novembro (11 a 15 de novembro)
13 de dezembro (11 a 15 de dezembro)
11 de janeiro (9 a 13 de janeiro)
10 de fevereiro (8 a 12 de fevereiro)
12 de março (10 a 14 de março)
10 de abril (8 a 12 de abril)
10 de maio (8 a 12 de maio)
9 junho (7 a 11 de junho)

Sequência de instalação das armadilhas:

1° dia: parcelas b11 e e14
2° dia: capoeira (2 armadilhas) e "ponto 1"
3° dia: floresta (3 armadilhas)

(2) Coletas durante o dia

Plantas de consórcio:
As coletas são efetuadas, a cada dois meses, em parcela de consórcio, com 100% de adubação com e sem micorriza. Estas serão comparadas as parcelas testemunhas (monocultivos de pupunha, seringueira, cupuaçu e citrus). O sorteio é aleatório de 3 parcelas de cada sistema, totalizando 9 parcelas.

A seguir, o número de plantas vistoriadas por parcela em cada sistema:

Sistema 1
Seringueira (24 plantas)
Cupuaçu (10 plantas)
Pupunha (64 plantas)
Mamão (38 plantas)

Sistema 2
Cupuaçu (15 plantas)
Pupunha (32 plantas)
Urucum (24 plantas)
Castanha (12 plantas)

Sistema 3
Seringueira (16 plantas)
Cupuaçu (5 plantas)
Coco (8 plantas)
Citrus (10 plantas)
Paricá (5 plantas)

O sistema 4 composto de seringueira, mogno, andiroba e paricá, foi vistoriado bimestralmente na seguinte forma:

Sistema 4
Seringueira (12 plantas)
Mogno (4 plantas)
Andiroba (4 plantas)
Paricá (12 plantas)

Nas culturas anuais procedeu-se da seguinte forma:

- Na mandioca, foram coletadas aleatoriamente 20 folhas por grupo de linhas, sendo quantificados e qualificados os insetos.

- No feijão, as coletas foram feitas com varredura, passando a rede entomológica cinco vezes aleatoriamente em cada grupo de linha de feijão, perfazendo uma amostra composta, totalizando quatro amostras.

- No milho, sorteou-se uma linha de cada grupo, recolhendo-se o material encontrado.

Coletas de insetos em plantas de monocultivo:

Sortearam-se 3 parcelas, por sistema (sistema 6, 7, 8, 9), totalizando 12 parcelas, observando-se 48 plantas de seringueira, 30 de citrus, 30 de cupuaçu e 115 de pupunha.

Coletas de insetos em plantas da área de vegetação espontânea:

Na área de vegetação espontânea (sistema 5), onde foram sorteadas 3 parcelas, foram feitas 5 varreduras em 3 posições da parcela, de forma a ter-se uma amostra composta, com vistoria trimestral.

Calendário da coleta durante o dia:

- Parcelas de consórcio (100 % de adubação): junho, agosto, outubro e dezembro, 1993; abril, junho, 1994;

- parcelas de consórcio (30 % de adubação): junho, setembro e novembro, 1993; janeiro, março, maio e julho, 1994;
- parcelas de monocultivo: junho, agosto, outubro e dezembro, 1993; fevereiro, abril e junho, 1994;
- vegetação de pousio (sist. 5): julho e outubro, 1993; janeiro, abril e julho, 1994.

3 Parâmetros a serem analisados conforme o método de coleta:

a. Classificação taxonômica dos insetos coletados nas culturas, potencialmente pragas.
b. Número e frequência de espécies, nos sistemas e áreas adjascentes;
c. Relação entre freqüência das pragas e dados metereológicos: temperatura máxima, mínima e média (°C); umidade relativa (%); pluviosidade (mm); insolação (hs); vento (m/s); pressão barométrica (mm), a serem obtidos no Setor de Meteorologia do CPAA;
d. Dominância
e. Flutuação populacional das pragas coletadas nas espécies vegetais estudadas.

4 Resultados parciais

4.1 Pragas nas culturas

Mandioca (*Manihot esculenta*)

Erinnys ello (L. 1758), Lepidoptera - Sphingidae, carateriza-se por sua alta voracidade, sobre tudo no último estágio larval, quando um individuo pode consumir até 11 decímetros quadrados de superficie foliar. O ciclo biológico, dura aproximadamente 45 dias, variando de 32 a 49 dias. O total de ovos que uma fêmea oviposita pode chegar a 1850 ovos. A fase larval tem duração de 12 a 15 dias, dependendo das condições climáticas. A larva passa por cinco instares, com quatro mudas de pele, através das quais aumenta de tamanho até aproximadamente 12 centímetros. As larvas de *E. ello*, são polífagas e podem alimentar-se de mais de 35 espécies diferentes de vegetais, pertenecentes principalmente as famílias *Euphorbiaceae*, *Caricaceae* e *Solanaceae*. O surto foi registrado em julho e agosto de 1993, o controle tem sido com catação manual. Na Figura 1, é apresentada a distribuiçao média de lagartas / parcelas / bloco, onde observa-se redução do número de indivíduos no plantio.

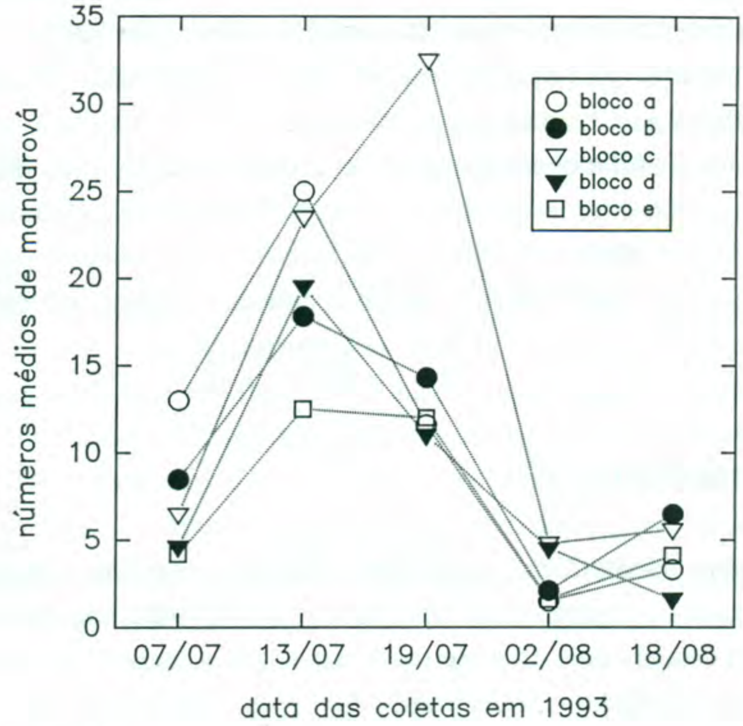

Figura 2:
Coleta manual de mandarová (*Erinnys ello*) em mandioca (média de lagarta por parcela/bloco), julho e agosto de 1993

Outros insetos pragas que apareceram em quantidades pequena, não chegando a 1% foram:

- Mosca da mandioca - Diptera - Lonchaeidae (McAlpine & Steyckal 1982), *Neosilba sp.*
- Thrips (Thysanoptera, família - Thripidae) - *Scirtothrips manihot*
- Cecidia (Diptera - Cecidomyidae) - *Jatrophobia brasiliensis* (Ruebsaamen, 1907).
- Mosca branca (Hemiptera, família - Aleyrodidae), ainda sem identificação taxonômica.

A exceção da Cecídia, os demais insetos desapareceram do plantio. Está não é preocupante, pois na mandioca não ocasiona problema.

Citrus (*Citrus sinensis*)
O desenvolvimento das plantas de citrus nos consórcios estão bem acima das plantas das parcelas testemunhas, e apresentam o mínimo de ataque de pragas. Nas inspeções os insetos encontrados foram:

- Cochonilha parda - Homoptera, Coccidae - *Saissetia coffeae* (Walker, 1852).
- Escama farinha - Homoptera, Diaspididae - *Pinnaspis* sp.
- Pulgão preto - Homoptera, super-família - Aphidoidea, família Aphididae - *Toxoptera* sp.
- Hemiptera, família coreidae, sugando brotos novos (sem identificação).

Todos os insetos não ultrapassaram 10% de ataque, e o controle tem obedecido a re-infestação nas plantas localizadas (Tabela 2), principalmente no caso das parcelas testemunhas, muito maiores, em relação as consorciadas.

Milho (*Zea mais*)
Os insetos encontrados foram:

- Cigarrinha - Homoptera, Cicadelidae - *Deois incompleta* - presença esporádica.
- Broca do colmo - *Diatraea sacharalis* (Fabr, 1794), Lepidoptera - Pyralidae, atacando espigas com 10% de dano, associada a lagarta do cartucho.
- Lagarta do cartucho - *Spodoptera frugiperda* (J.E. Smith, 1797), Lepidoptera, Noctuidae, associada a broca do colmo.

O controle foi feito semanalmente, até o início da maturação dos grãos, totalizando cinco aplicações (Tabela 2), não se verificando maiores danos a colheita.

Feijão caupi (*Vigna sp.*)
Essa cultura sofreu violento ataque de vaquinha *Diabrotica speciosa* (Germar,1824) Coleoptera - Chrysomelidae. A citada espécie evidência-se ser praga de fundamental importância econômica à cultura, com prejuízos estimados em 90% da produção. A ocorrência de grande número de vaquinha deveu-se a presença da cobertura de solo da área experimental com puerária (*Pueraria phaseoloides*, leguminosa), infestada do inseto praga. Não houve condições de controle em virtude do tamanho da área coberta. O inseto tem preferência por feijão, soja e solanáceas em geral, tendo na puerária uma de suas plantas hospedeiras.

Várias tentativas de controle foram efetuadas (Tabela 2), não surtindo efeito em virtude da quantidade de insetos presentes nas vizinhanças do plantio.

Pupunha (*Bactris gasipaes*)
Nos primeiros meses de implantação das pupunheiras houve ataque de cochonilha (ainda sem identificação), localizado principalmente no Bloco b. Foi procedido o controle (Tabela 2) e a cultura encontra-se em pleno desenvolvimento e sem problemas de pragas.

Paricá (*Schizolobium amazonicum*)

Nos meses de setembro/93, algumas plantas de paricá apresentaram morte da gema apical. Examinando o material, verificou-se a presença de insetos sugadores (Homóptero sem identificação). Foram localizados ataques nos Blocos a, b e d, e efetuada aplicação de produto químico em todas as plantas (Tabela 1). No mês de outubro, oito plantas ainda tinham o problema, efetuou-se, então, nova aplicação. Atualmente, as plantas encontram-se em pleno desenvolvimento, ultrapassando os 2,5 m de altura. No entanto as oito plantas reicidentes apresentam bifurcação no ápice.

Outro problema que se tem verificado é o ataque de gafanhotos, principalmente na forma jovem - (Orthoptera, Acrididae), ocasionando perdas de área foliar, sem no entanto prejudicar a cultura. Esses insetos são encontrados na vegetação rasteira da área experimental, não sendo possível o seu controle. No entanto, o uso de outros métodos, entre eles o rebaixamento da cobertura, minimiza a incidência da praga. As culturas mais atacadas por gafanhoto tem sido: cupuaçu, citrus, pupunheira, urucum, castanheira.

Cupuaçu (*Theobroma grandiflorum*)

Essa cultura no mês de outubro, teve plantas dos Blocos b e c, atacadas por broca da ponteira (coleóptera sem identificação). Em virtude do pequeno número de plantas atacadas (3), foi feito apenas o acompanhamento da praga.

Mamão (*Carica papaya*)

Nos mamoeiros tem havido questionamento quanto à presença de pequenos coleópteros negros sem identificação. Nas inspeções não se verificou qualquer dano do mesmo nas plantas.

Tabela 1:

Produtos usados no controle de pragas na área experimental

Produto	Dosagem	Cultura	Praga	Período	Interv.	N° de Vezes
Carbaryl	1ml/l d'água	Milho	Lag. da espiga	Julho/agosto	Semanal	05
Carbaryl	1ml/l d'água	Feijão	Vaquinha	Julho	Semanal	03
Dipterex	1ml/l d'água	Feijão	Vaquinha	Julho	Semanal	01
Dodecacloro	30g/trilha	-	Saúvas	Outubro	-	01
Azodrin	1ml/l d'água	Pupunha	Cochonilhas	Agosto	-	01
Phosdrin	1ml/l d'água	Paricá	Hom. da ponteira	Setembro	-	01
Dipterex	1ml/l d'água	Paricá	Hom. da ponteira	Outubro	-	01
Fungo *Aschersonia* sp.	1gr/l d'água	Cítrus	Cochonilhas	Agosto	-	01

4.2 Varredura

Foram coletados e identificados os seguintes insetos:

Ordem: Coleoptera
    Família: Chrysomelidae
        Diabrotica speciosa (Germar 1824)
Ordem: Hemiptera
    Família: Coreidae
        Chrynocerus sanctus
    Família: Pentatomidae
        Oebalus poecilus
Ordem: Homoptera
    Família: Cercopidae
        Deois incompleta
Ordem: Hymenoptera
    Família: Formicidae
        Ectatoma sp.

Além disso, houve ocorrência de espécies de formigas cortadeiras (saúvas) *Atta sexdens* (L., 1758) e *Atta laevigata* (F. Smith. 1858). O controle foi feito com iscas envenenadas, na base de 30 g por porta-isca, colocado próximo aos olheiros ativos.

Têm sido coletados indivíduos da classe Aracnidea. Vale o registro por tratar-se de importantes predadores de insetos. No geral foram colhidos 11 indivíduos.

Não se pode analisar a predominância de insetos por tratamentos, devido ao pouco tempo de coleta. No sistema composto de cupuaçuzeiros (7) houve maior coleta de insetos. No de citrus (9) houve maior incidência de pragas com hemípteros e cochonilhas, ocasionando alguns problemas, controlados com produto químico.

4.3 Coleta com armadilha luminosa

As armadilhas foram instaladas em três ambientes e alturas diferentes, durante a fase de dominância da lua nova. Foram capturados 22.696 indivíduos, pertencentes a 14 ordens e 600 espécies. Em termos de número de indivíduos, a predominância ficou para a ordem Hymenoptera a 1,5 m de altura, vindo a seguir a ordem Lepidoptera com bom número de espécies principalmente da família Sphingidae. No entanto, o ambiente mais diversificado em termos de espécie foi a floresta quando comparada com outros a mesma altura. A Figura 2 mostra os números de espécies e de indivíduos coletados a 1,5 m de altura, das quatro ordens principais, apresentado em um diagrama de ordenação. A distribuição espacial dos quatro grupos é bem diversa, assim como das ordens com diferentes números de indivíduos e espécies.

Os resultados são poucos em virtude do pequeno tempo de coleta, agravado, principalmente, pelo excesso de chuvas que tem ocorrido no período. Assim, no mês de setembro, chegou a inviabilizar a coleta. Alem disso, outros problemas têm concorrido para perda de alguns dados, entre estes citamos a instabilidade das baterias que, embora novas, tem apresentado sérios problemas de descargas, não sendo possível prever o acidente. Se esse fato ocorre no início do período de domínio da lua, haverá tempo para repetir a coleta, no entanto se ocorrer nos dois últimos dias a perda é inevitável.

Diante do exposto, será analisado a continuidade da coleta com armadilha. Caso seja decidido pelo encerramento desta parte do trabalho, o mesmo ficará até completar um ano de coleta dos dados, para poder fazerem-se as análises.

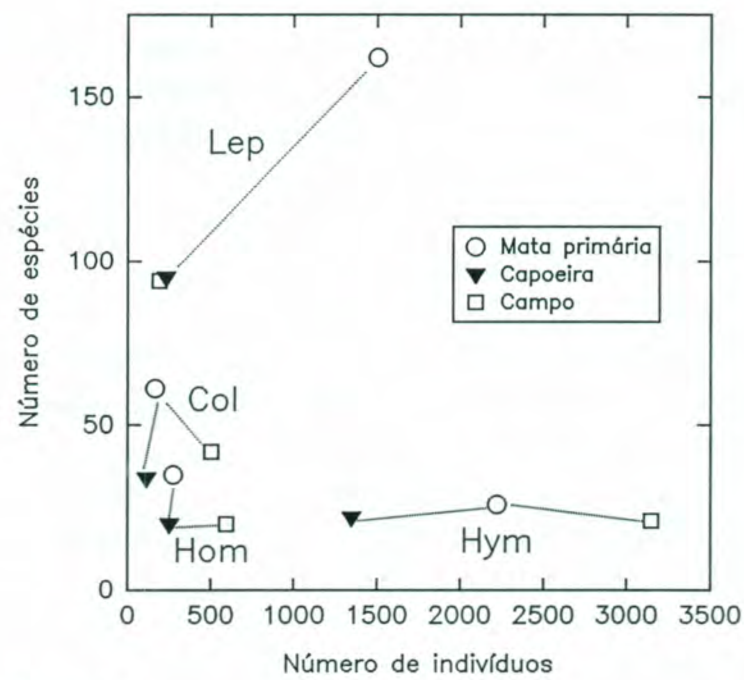

Figura 2:
Ordenação do número de indivíduos e de espécies das principais ordens coletadas em armadilhas luminosas a 1,5m de altura (Col = Coleoptera, Hom = Homoptera, Hym = Hymenoptera, Lep = Lepidoptera)

5 Continuação do trabalho

O levantamento nos consórcios e nos arredores continuará sem alterações na metodologia, até junho 1994, para completar um ano de observação. Depois, o trabalho concentra-se nas atividades seguintes:

1. Observar o desenvolvimento de insetos pragas no campo; concentrar a atenção nas espécies danosas às plantas; documentar as pragas com fotografias;
2. Identificar os insetos coletados;
3. Avaliar os dados coletados; questão principal: Quais são os grupos de insetos pragas das plantas úteis, e quais são seus ambientes nativos?

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Solos e nutrição de plantas

Newton Bueno

Zusammenfassung:

Böden und Pflanzenernährung

Die traditionelle Wirtschaftsweise (Roden, Brennen, Brache) auf den von Natur aus nährstoffarmen Böden hat sich als inadequat erwiesen, weil es dadurch zu Bodenerosion und -auswaschung kommt. Alternativen wurden erprobt, indem die Brachen, angeregt durch die PROBUR-Projekte, mit Kautschuk bepflanzt wurden, später versuchte man Rekultivierungen mit exotischen Kulturen. Heute werden agroforstliche Systeme als wichtig für den Bodenschutz, eine Produktion für lange Zeit am selben Ort, um die Wanderfeldwirtschaft zu verhindern und zur ausgewogenen Dekompostierung des vorhandenen pflanzlichen Materials angesehen. - Die Studie im Rahmen des SHIFT-Projekts mit verschiedenen Produktionssystemen muß zum Ziel haben, die physikalischen und chemischen Änderungen des Bodens zu begleiten und im Sinne einer Entwicklung der Produktivität zu steuern. Die Daten der Tab. 2 zeigen, wie unverzichtbar zumindest für die exotischen Kulturen Kalkung und Düngung sind. Die Al^{3+}-Konzentrationen des Bodens könnten bei den vorliegenden sauren Böden Probleme darstellen, was beim Maniok der Fall war.

1 Introdução

No Amazonas predominam solos de baixa fertilidade natural, que vêm sendo utilizados no sistema de cultivo migratório (desmatamento, queima, cultivo e abandono). Esta extratégia de manejo do solo tem se mostrado inadequada provocando perdas de nutrientes por erosão e lixiviação, acelerando o processo de diminuição da fertilidade do solo, efeitos que são comentados e mostrados por LEAL (1987), LOPES et al. (1987) e YOUNG (1990).

Mais recentemente registra-se uma crescente introdução de culturas exóticas como meio de ocupar áreas abandonadas, antes sob cultivo da seringueira incentivado pelos PROBOR's I, II e III. Isto tem exigido a busca de estratégias alternativas para o uso eficiente destes solos.

Dado que é difícil, pelo menos para os pequenos e médios agricultores usarem regularmente os insumos agrícolas do tipo corretivos e fertilizantes para melhoria e manutenção da produtividade destas área, o uso de sistemas agroflorestais é de extrema importância como fonte geradora de riquezas e de melhoria e manutenção do ambiente, pela proteção do solo, produção em geral por tempo mais longo na mesma área evitando a agricultura migratória, por proporcionar o aporte contínuo e abundante de resíduos vegetais, contrabalançando a rápida decomposição da matéria orgânica e, principalmente, por ser uma prática que proporciona rendimentos econômicos ao agricultor durante todo o ano.

Neste estudo com diferentes arranjos de sistemas de produção tem-se por objetivo acompanhar as modificações das características físicas e químicas do solo e o desenvolvimento e produtividade das diferentes culturas estudadas.

2 Metodologia

Para atingir os objetivos, os esquemas de adubação foram organizados para separar a adubação de plantio das adubações de desenvolvimento e de produção, especialmente para as culturas perenes e semi-perenes. No caso da adubação de plantio são previstas adubações da cova de plantio e de cobertura no plantio com os tratamentos de: a) 100% da recomendação oficial e b) 30% da recomendação oficial, para cada cultura, obedecidas as referências bibliográficas. Detalhes do esquema de adubação são apresentados na contribuição de *Macêdo, Nunes & Schmidt*.

Foram coletadas amostras de solo por parcela e as características químicas médias de cada parcela, estão na Tabela 1, cujos resultados foram obtidos no laboratório de Análises de Solo e Plantas do CPAA.

3 Resultados e discussões

Os dados da Tabela 1 mostram que, pelo menos para as culturas exóticas usadas neste estudo, como laranja, milho e mamão, a calagem e adubação são duas práticas imprescindíveis, em virtude da elevada e generalizada acidez e da pobreza de nutrientes deste Latossolo Amarelo de textura muito argilosa. Os dados de SMYTH & CRAVO (1966-1967) confirmam esta necessidade, para o milho. Os resultados da Tabela 2 sugerem ainda que neste caso é necessário conhecer bem a estreita influência de calagem na potencialização do efeito dos fertilizantes para promover a melhor relação custo/benefício no espaço e no tempo.

Registra-se que os valores de concentração de Al^{3+} trocável são tão elevados que até mesmo as culturas adaptadas a condições de solos ácidos podem sofrer limitações. Este foi o caso da mandioca, que por falta de tempo não recebeu adubação na cova de plantio e em setembro já apresentava sintomas de distúrbios nutricionais. Na cultura como um todo observou-se uma clorose e depois necrose nas margens e pontas das folhas mais velhas ou mesmo internerval, às vezes seguida pelo desenvolvimento de cor alaranjada ou vermelha, sugerindo distribuição de potássio e/ou magnésio no tecido. Foram coletadas amostras de plantas, separando-se na mesma planta as folhas com sintomas visuais de distúrbios nutricionais das folhas sem sintomas. Foram coletadas em todas as plantas de cada parcela, duas folhas por planta no sentido leste-oeste. Para cada parcela foram coletadas 5 amostras simples na profundidade de 0-20cm, formando uma amostra composta. Todo o material devidamente identificado foi encaminhado para o laboratório de Análises de Solos e Planta para as devidas determinações.

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Tabela 1:
Características químicas (em valores médios extremos) do solo de cada parcela experimental.
(coleta em abril/93, análise em maio/93 no LASP)

	pH (H_2O)	P ppm	K ppm	Ca me%	Mg me%	Al me%	M.O. %
FS[1]	4,7-5,0	4-10	12-38	0,02-0,06	0,05-0,13	1,3-2,3	2,41-5,28
PS [2]	4,6-5,0	3-06	16-56	0,03-0,53	0,05-0,17	1,2-2,2	2,48-3,70
A[3]	4,2-4,8	3-10	20-44	0,02-0,21	0,05-0,13	1,4-2,4	3,30-4,73
B	4,7-5,0	6-10	24-40	0,04-0,25	0,07-0,20	1,5-2,3	3,02-5,01
C	4,4-5,2	3-50	14-88	0,08-1,34	0,07-1,16	0,9-2,5	2,41-6,79
D	4,4-5,0	3-09	22-48	0,06-1,05	0,05-0,49	1,0-2,4	2,55-5,07
E	4,6-5,2	2-06	12-44	0,07-1,61	0,06-0,42	0,6-1,8	2,68-5,14
A/5	4,2-4,8	1-12	4-28	0,02-0,19	0,02-0,17	0,7-1,7	0,76-4,39
B_{10}	4,3-4,7	1-07	4-24	0,04-0,08	0,02-0,07	0,8-1,9	0,34-5,28
C_{11}	4,2-4,7	1	4-12	0,04-0,18	0,07-0,06	0,6-1,5	0,28-2,41
D_6	4,5-4,8	1-05	6-30	0,11-0,56	0,05-0,16	0,9-1,7	0,69-5,83
E_{11}	4,8-5,4	1	6-58	0,07-1,39	0,03-1,11	0,4-1,0	0,41-4,25
A/6	4,2-6,0	5-50	18-50	0,07-3,72	0,07-1,23	0,3-2,8	2,89-6,04
C/5	4,2-5,0	5-10	20-50	0,07-0,69	0,08-0,20	1,0-3,3	3,90-7,14
E 16	4,0-6,2	3-19	16-44	0,05-3,98	0,06-1,11	0,2-2,6	3,37-7,07

(1) Floresta secundária

(2) plantação de *Schmidt*

(3) As letras alfabéticas identificam as demais parcelas, conforme o arranjo do sistema.

Biomassenproduktion und Nährelementgehalt ausgewählter Pflanzenarten agroforstlicher Plantagen im Amazonasgebiet

Petra Schmidt

Resumo:

Produção de biomassa e teor de nutrientes em espécies de plantas selecionadas de sistemas agroflorestais na Amazônia

Está sendo conduzido um estudo sobre produção de biomassa e teores de elementos minerais em plantas úteis selecionadas e em solos dos sistemas agroflorestais na área experimental do projeto SHIFT, para determinar se os nutrientes fornecidos ficarão disponíveis para as plantas até atingirem o uso sustentável da plantação. Determinaram-se a produção de biomassa e o teor de nutrientes no interior de diferentes tecidos em plantas inoculadas com fungos micorrízicos vesicular - arbusculares (MVA) e nas plantas testemunhas, com três a seis meses de idade. A disponibilidade de nutrientes para as plantas, no solo, foi analisada antes e após a queima da área experimental. A produção de biomassa foi semelhante entre as plantas inoculadas com MVA e as plantas testemunhas. As diferentes análises das amostras de solo, antes e após a queima, mostraram um aumento distinto de Ca, Mg e K após a queima. Entretanto, o pH do solo decresceu após a queima. As análises do conteúdo total de alumínio e de Al^{+3} demonstraram que a quantidade de alumínio disponível para as plantas é muito menor do que o conteúdo total de alumínio no solo.

Summary:

Biomass production and nutrient content of selected plant species of agroforestry plantations in the Amazon

The study on biomass production and mineral elements in selected useful plants and soils of the different systems in the SHIFT experimental area is conducted to find out whether the nutrient supply will last for the plants planted, to achieve a sustainable use of the plantation. The biomass and the nutrient content within the various tissues from three to six months old VAM-inoculated and control plants were determined. The available plant nutrients were analysed in the soil before and after burning. The biomass does not show any differences between VAM-inoculated and control plants. The different analyses of the soil samples before and after burning showed a sharp increase of Ca, Mg or K after burning. In contrast, soil pH decreased after burning. The analyses of the total content of aluminium and of Al^{3+} demonstrated, that the aluminium availability for plants is much lower than the whole aluminium content of the soil.

1 Einleitung

Die vorliegende Studie über die Biomasseproduktion und die Nährelemente in ausgewählten Pflanzen soll Aufschluß darüber geben, inwieweit für die agroforstlichen Systeme des SHIFT-Projektes eine nachhaltige Mineralelementversorgung gewährleistet ist. Hierfür werden die Biomasse sowie der Elementgehalt in einzelnen Pflanzengeweben ermittelt und zusätzlich die im Boden pflanzenverfügbaren Mineralelemente untersucht.

2 Material und Methoden

2.1 Anlage einer Referenzfläche

Da für die Biomassebestimmung und die Bestimmung der Elementgehalte in den Pflanzen ganze Pflanzen samt Wurzeln entnommen werden müssen wurde, um eine zu extreme Störung einzelner Parzellen in der Plantage zu vermeiden, direkt neben der eigentlichen Projektfläche eine Referenzfläche angelegt.

In geringem zeitlichen Abstand zur eigentlichen Projektanlage wurden dort gleichaltrige Anzuchtpflanzen von Cupuaçu, Urucum, Mogno, Paricá, Pupunha und Andiroba gepflanzt.

Die Pflanzung erfolgte in Reihen mit einem Abstand innerhalb der Reihen von 4m zwischen den Pflanzen (ausgenommen Pupunha, die in einem Abstand von 2m gepflanzt wurde) und Abständen zwischen den Reihen zwischen 5 und 6 Metern. Alternierend wurde je Pflanzenart eine inokulierte sowie eine nicht inokulierte Pflanze gepflanzt und mit den gleichen Düngungsstufen der eigentlichen Plantage versehen (Düngungsmengen und -zusammensetzungen s. *Macêdo, Nunes & Schmidt*).

Um genaueren Aufschluß auf die Auswirkung des Düngers auf Biomasseproduktion und den Elementgehalt einiger Pflanzen zu erhalten, wurden für Mogno und Cupuaçu zusätzlich Nullvarianten und 60% Düngerstufen mit folgenden Düngergaben eingesetzt:

Düngergabe Mogno:
300g Kalk, 93g Supertripelphosphat (STP), 60g Kaliumchlorid (KCl) ins Pflanzloch, nach 30 Tagen 39g Harntoff (HS) und zusätzlich im ersten Jahr 66,6g HS, 133,2g STP sowie 49,8g KCl.

Düngergabe Cupuaçu:
300g Kalk, 60g STP, 18g KCl, 3g Borat ins Pflanzloch, nach 30 und 60 Tagen je 13,2g HS und nach 60 sowie 120 Tagen je 18g KCl.

Alle anderen Pflegemaßnahmen wie Hacken der Sekundärvegetation, Pflanzenschutzeinsatz oder Zurückschneiden bestimmter Pflanzen werden entsprechend der eigentlichen Plantage durchgeführt.

2.2 Biomassebestimmung und Bestimmung der Elementgehalte in den Pflanzen

Die Bestimmung der Biomasseproduktion sowie der Elementgehalte erfolgte nach der selben Methodik des letzten Jahres (vgl. Jahresbericht 1992).

Ganze Pflanzen wurden samt Wurzeln entnommen, fraktioniert und für die Bestimmung der Biomasseproduktion 3 Tage bei 103°C gedarrt. Zur Ermittlung der Elementgehalte mittels ICP-OES (Inductively coupled argon plasma with optical-emission-spectrometry) wurden die fraktionierten Proben gemahlen, mit Salpetersäure versetzt und aufgeschlossen. Genauere Präparation des Probenmaterials und Aufbau der Analyseeinheit können Schönburg (1987) sowie Rademacher (1986) entnommen werden. Die Analysen der Proben nach der ICP-OES-Methode sind noch nicht abgeschlossen.

Die Biomassebestimmungen sowie die Ermittlung der Elementgehalte wurden für die restlichen drei bis sechs Monate alten Anzuchtpflanzen von *Bactris gasipaes*, *Bertholletia excelsia, Bixa orellana, Cedrela odorata, Cocos nucifera, Dipterix alata, Elais guineensis, Hevea spec., Schizolobium amazonicum, Swietenia macrohylla* und *Theobroma grandiflorum* durchgeführt. Dabei wurden je zwei inokulierte sowie zwei nicht inokulierte Pflanzen untersucht.

2.3 Nährstoffanalysen der Bodenproben

Da die Nährstoffgehalte des Bodens eine große Rolle für die Nährstoffsituation innerhalb der Pflanzen und somit für die gesamten Pflanzsysteme und deren dauerhafte Nutzung spielt, wurden zusätzliche Elementanalysen von Bodenproben durchgeführt.

Untersucht wurde eine Mischprobe der Erde aus den Anzuchtbeuteln der oben genannten drei bis sechs Monate alten Pflanzen sowie 6 Bodenproben (21, 22, 23, 28, 29, 30) aus der Bodenprobennahme vor der Brandrodung, 7 Bodenproben (F3 26, F3 27, F3 28, F3 31, F3 32, F3 33, F3 36) die direkt nach dem Brand gezogen wurden sowie 16 Bodenproben (PS 1-PS 6, D6/1-D6/10) aus der Bodenprobennahme ca. 6

Monate nach der Brandrodung. Ausgewählt wurden dabei Proben, die in der Nähe bez. direkt auf der Referenzfläche genommen wurden. Bei den Proben D6/1-D6/10 handelt es sich um Bodenproben, die in Parzelle D6 in Tiefen von 0-1 m in 10 cm Schritten gezogen wurden (Art der Bodenprobennahme s. *Tavares et al.*).

Für sämtliche Proben wurden eine Bestimmung der effektiven Austauschkapazität (AKe) durchgeführt, die Gleichgewichtsbodenlösung (GBL) ermittelt und mit denselben Bodenlösungen eine Alumiuniumspeziierung durchgeführt sowie deren pH-Wert bestimmt.

Die Analyse der Bodenproben erfolgte an der Niedersächsischen Forstwirtshaftlichen Versuchsanstalt in Göttingen.

2.2.1 Bestimmung der effektiven Austauschkapazität (AKe)

Als effektive Austauschkapazität bezeichnet man die Summe aller an der Bodenoberfläche beim jeweiligen pH des Bodens austauschbar gebundenen Kationen, die nach Meiwes et al. (1984) in ökologischer Sicht den mobilisierbaren Kationenvorrat im Boden darstellen.

Bei der Bestimmung der AKe werden die austauschbar gebundenen Kationen des Bodens gegen NH4-Ionen ausgetauscht. Hierfür wird luftgetrockneter und gesiebter Boden (2mm Sieb) im Perkolationsferfahren mit 1N NH4CL-Lösung versetzt. Der Austausch erfolgt bei einem großen Überschuß an NH_4^{+}-Ionen (Aufbau und Funktionsweise der Perkolationsapparatur siehe Meiwes et al. 1984).

Die Bestimmung der Kationengehalte in der Perkolationslösung erfolgt über die Messung mittels ICP. Ermittelt werden dabei alle quantitativ wichtigen Kationen - Na, K, Mg, Ca, Al, Mn, Fe und pH.

2.2.2 Gleichgewichtbodenlösung (GBL)

In der Gleichgewichtsbodenlösung, dem Sättigungsextrakt des Bodens, werden alle für die Kationen-Anionen-Bilanz quantitativ wichtigen Ionen bestimmt.

Man gewinnt die GBL, indem man dem Boden soviel Wasser hinzufügt, daß unter Rühren gerade eine Suspension ensteht. Für die Bestimmung des Lösungs/Boden-Verhältnisses wird der Wassergehalt der Bodenprobe ermittelt und die der Probe hinzugefügte Wassermenge festgehalten. Um einen gleichgewichtsnahen Zustand zu erreichen, läßt man die Suspension 24 Stunden unter gelegentlichem Rühren stehen. Die über eine mit Schwarzbandfilter versehene Nutsche gefilterte Bodenlösung wird mittels ICP analysiert, wobei die folgenden Kationen und Anionen bestimmt werden: Na, K, Mg, Ca, Al, Mn, Fe, P und S (nach Meiwes et al. 1984).

2.2.3 Aluminium-Speziierung

Die Gesamt-Aluminiumgehalte in den Böden der Projektfläche sind relativ hoch (vgl. *Bueno*). Um Aufschluß darüber zu erhalten, wie hoch der pflanzenverfügbare und somit der für die Pflanzen toxische Gehalt an Al^{3+} ist, wurde der Gesamtgehalt an organisch gebundenem Aluminium mittels Aluminiumspeziierung bestimmt. Hierfür wurden die Probenlösungen der GBL-Messung mit einem Ionenaustauscher versehen, um die anorganischen Hydrolysekomplexe des Aluminiums an diesen zu binden. Die organischen Aluminiumkomplexe werden aufgrund ihrer geringen positiven Ladung nicht am Kationenaustauscher gebunden und verbleiben in der Lösung. Die Differenz zwischen dem komplexierten anorganischen Anteil des Aluminiums und dem Gesamtanteil an Aluminium ergibt den Gehalt des organischen Anteils in der Bodenprobe.

2.2.4 pH-Wert Bestimmung der GBL-Lösungen

Da der pH-Wert des Bodens eine wichtige Rolle für biologische und chemische Prozesse im Boden spielt und somit u.a. auch die Interaktionen VAM - höhere Pflanze sowie Nährstoffverfügbarkeit und -aufnahme der Pflanzen beinflußt, wurden die pH-Werte der einzelnen Bodenproben in den GBL-Lösugen mit Hilfe einer Glaselektrode bestimmt.

3 Erste Resultate

3.1 Biomassebestimmung und Bestimmung der Elementgehalte in den Pflanzen

Die Bestimmung der Biomasseproduktion der drei bis sechs Monate alten Anzuchtpflanzen ergab, daß in diesem Stadium die Biomasse des oberirdischen Sprosses mit Trockenmassen um die 80% weitaus größer ist als die der Wurzeln mit Trockengewichten um die 20%. Signifikante Unterschiede in der Biomasse zwischen inokulierten und nicht inokulierten Pflanzen wurden bei keiner der Arten gefunden. Die Ergebnisse der weiteren ICP-OES-Analysen liegen bisher noch nicht vor.

3.2 Nährstoffanalsen der Bodenproben

3.2.1 Bestimung der effektiven Austauschkapazität (AKe)

Betrachtet man die Summe der AKe (Abb. 1), so zeigt sich, daß sich der Gesamtgehalt der Kationen in den Bodenproben nach der Brandrodung nicht wesentlich verändert hat. Es ist lediglich eine leichte Abnahme um ca. 10% zu verzeichnen. Nach 6 Monaten entsprechen die Kationengehalte im Boden in etwa wieder den Verhältnissen vor der Brandrodung.

Deutliche Änderungen im Kationengehalt zeigen sich hingegen bei der Bodenabstufung in 10 cm Schritten. Den höchsten Gehalt mit 37,1% weist der Boden der obersten 10 cm auf. Nach unten hin nehmen die Kationengehalte deutlich ab und erreichen in 1 m Tiefe schließlich einen Wert von nur 12,7%.

Betrachtet man die einzelnen Elementgehalte der Bodenproben, so zeigen sich deutliche Unterschiede zwischen den Proben vor und denen nach der Brandrodung. So werden direkt nach dem Brand offensichtlich Mangan (Abb. 2), Kalium (Abb. 3), Magnesium (Abb. 4) und Calcium (Abb. 5) freigesetzt, die Werte steigen zumindest deutlich an, bei Calcium über 20%. Die Gehalte von Natrium (Abb. 6), Aluminium (Abb. 7) und Eisen (Abb. 8) nehmen hingegen nach der Brandrodung leicht ab.

Nach 6 Monaten entsprechen die Werte jedoch bei allen Elementen fast wieder den Gehalten der Bodenproben vor der Brandrodung. Leichte Unterschiede zeigen sich lediglich bei Mangan, Calcium und Eisen. Die Bodenproben der Bodenabstufungen zeigen, daß die Gehalte von Magnesium, Kalium, Calcium, Mangan und Eisen in den unteren Bodenschichten abnehmen. Bei Mangan und Eisen sind die Unterschiede zwischen den oberen 20 cm und der Bodenprobe in 1 m Tiefe besonders deutlich ausgeprägt. Die Gehalte von Aluminium und Natrium nehmen dagegen zu den unteren Bodenschichten hin zu. Bei Natrium nimmt der Gehalt allerdings in 1 m Tiefe nach einer deutlichen Zunahme in 90 cm Tiefe extrem ab.

Vergleicht man die Analysenwerte der einzelnen Kationen miteinander, so wird deutlich, daß der Gehalt an Aluminium mit Werten zwischen 40% und 90% der Summe der AKe in allen Bodenproben extrem hoch ist (Abb. 1).

3.2.2 Gleichgewichtsbodenlösung (GBL)

Die Ergebnisse der GBL zeigen die gleichen Tendenzen wie die der AKe, jedoch sind sie hier ausgeprägter. Lediglich die Aluminiumwerte unterscheiden sich von der

Tendenz her deutlich von denen der AKe-Werte (Abb. 9-15). Sie nehmen nach der Brandrodung extrem ab und erhöhen sich auch nach 6 Monaten nicht. Im Vergleich zu anderen Elementen weisen die Aluminiumgehalte der GBL ebenfalls völlig andere Ergebnisse auf als die der AKe. Mit Gehalten zwischen 1-6 ppm vor der Brandrodung und 0-2 ppm nach der Brandrodung liegen die Werte deutlich unter denen einiger anderer Elemente, z.B. Kalium mit Werten bis zu 30 ppm.

3.2.3 Aluminium-Speziierung

Die Aluminium-Speziierung verdeutlicht, daß der organische Anteil an Aluminium in den Bodenproben vor der Brandrodung im Verhältnis zum Gesamt-Aluminiumgehalt relativ gering ist. Nach der Brandrodung ändert sich das Verhältnis deutlich, bei einigen Proben nimmt der organische Aluminiumanteil fast die Hälfte des Gesamt-Aluminiums ein. Dies verändert sich auch nach 6 Monaten kaum, jedoch liegt der Gesamtanteil an Aluminium nach der Brandrodung deutlich niedriger als vor dem Abbrennen (Abb. 16).

3.2.4 Bestimmung des pH-Wertes

Die pH-Werte der GBL-Lösungen liegen mit Werten zwischen 4 und 6 im mittleren Bereich mit Tedenz zur Acidität. Den niedrigsten pH-Wert weist mit 4 der Boden der Anzuchtbeutel auf, der aus einer Mischung aus Sand und Primärwaldboden im Verhältnis 1:4 besteht. Eine signifikannte Änderung des pH-Wertes nach der Brandrodung läßt sich nicht feststellen, es ist lediglich eine leichte Tendenz in den sauren Bereich zu verzeichnen. Auffällig ist, daß der Boden in einer Tiefe von ca. 70 cm deutlich alkalischer wird.

4 Diskussion

Primärwälder der tropischen Zone zeichnen sich im allgemeinen dadurch aus, daß ein Großteil der verfügbaren Nährelemente in den lebenden Pflanzengeweben gebunden ist (Santos 1985). Eine Brandrodung dieser sensiblen, durch kurze Nährstoffkreisläufe gekennzeichneten Systeme führt bei falscher Behandlung der Böden unweigerlich zu deren Nährstoffverarmung. Viele Flächen im Amazonasgebiet mußten auf diese Weise nach 3-4 jähriger Nutzung aufgegeben werden. Die Analysen der Elementgehalte verschiedener Pflanzen und der Böden derselben Standorte sollen Aufschluß darüben geben, inwieweit die verschiedenen Systeme des SHIFT-Projektes eine nachhaltige Nährelementversorgung gewährleisten.

Bei den nährstoffarmen Böden des Untersuchungsgebietes handelt es sich um sehr alte Aluvialböden, die nach Lavelle (1985) einen höheren Elementgehalt aufweisen als die in der tropischen Zone häufig auftretenden Oxisole. Die Fruchtbarkeit dieser Aluvialböden ist jedoch ebenfalls nicht besonders hoch. Änderungen der Elementgehalte in diesen Böden, die sich nach der Brandrodung ergeben, wurden bereits von verschiedenen Autoren beschrieben. So geben Brinkmann und Nascimento (1973) für gelben Latosol einen Anstieg der Calcium- und Magnesiumgehalte von 400% an. Jordan (1989) beschreibt ebenfalls eine deutliche Zuhnahme von Calcium-, Kalium- und Magnesium direkt nach dem Abbrennen. Nach längerer Brache stellte sich bei seinen Versuchen in etwa wieder die ursprüngliche Nährstoffsituation des Bodens ein. Diese Ergebnisse entsprechen völlig den hier erarbeiteten.

Die hohen Aluminiumgehalte verschiedener Pflanzenorgane (siehe Bericht 1992) in fast allen Arten machten eine genauere Untersuchung der Aluminiumgehalte des Bodens notwendig. Die Resultate der Aluminiumspeziierung zeigen, daß der Gesamgehalt an Aluminium zwar sehr hoch ist, der Gehalt an pflanzenverfügbarem, toxischem Aluminium jedoch verhältnismäßig gering. Um die trotzdem sehr hohe Anreicherung dieses Elementes in den Pflanzengeweben erklären zu können, wird daher zusätzlich der Wasserdurchfluß innerhalb einiger Pflanzenarten gemessen.

Die Brandrodung hat außer einer Änderung der Nährstoffsituation auch eine Änderung des pH-Wertes zur Folge. Lavelle (1985), der für Aluvialböden ebenfalls pH-Werte von ca. 5 angibt, beobachtete nach dem Abbrennen einen leichten Anstieg der pH-Werte, was auf die an basischen Kationen reiche Asche zurückzuführen ist. Die in dieser Studie gegensätzlichen Resultate können auf den Transport, die unterschiedlichen Temperaturen sowie die lange Lagerung der Bodenproben zurückgeführt werden. Laut Meiwes et al. (1984) handelt es sich bei dem pH-Wert um einen konventionellen, zeitlich und örtlich variablen Meßwert, der nicht nur von den Umsätzen innerhalb des belebten Bodens, sondern auch von der Bodenprobennahme und -behandlung abhängig ist. Die oben genannten Faktoren können demzufolge durchaus einen Einfluß auf den pH-Wert gehabt haben.

Der niedrige pH-Wert in den Anzuchtbeuteln ist offensichtlich auf die Acidität des Primärwaldbodens zurückzuführen. Der pH-Wert tropischer Primärwaldböden liegt laut Literaturangaben (Jordan 1989) zwischen 3 und 4. Mit Hilfe von Hochrechnungsmodellen wird es möglich sein, aus den Ergebnissen der Boden- und Pflanzenanalysen Bilanzen zu errechnen, die Aufschluß darüber geben, ob der Nährstoffgehalt des Bodens eine langfristige Elementversorgung der Pflanzen gewährleistet. Hierfür werden zur Zeit weitere Elementanalysen von älteren Pflanzen sowie der entsprechenden Bodenproben - durchgeführt.

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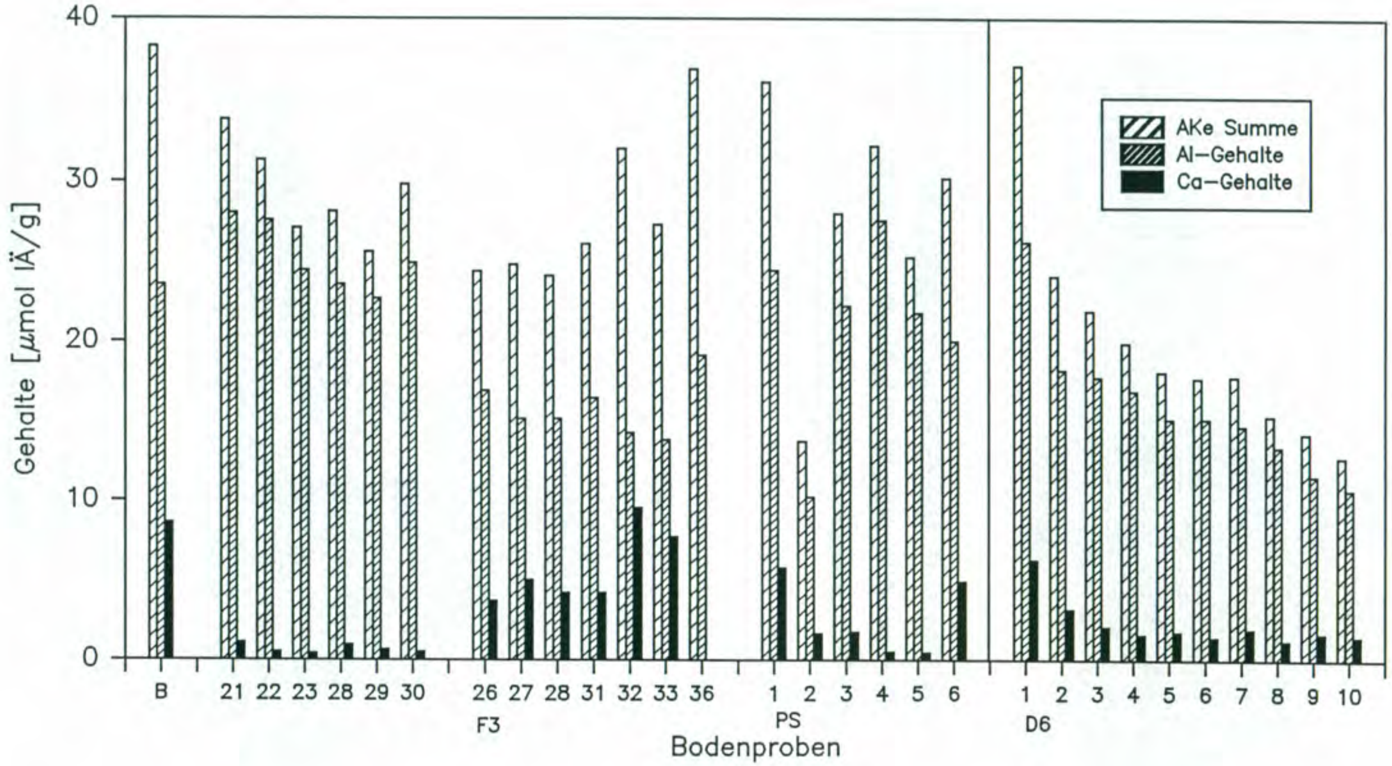


Abb. 1:

Summe der AKe im Vergleich zu Aluminium- und Calcium-Gehalten; B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

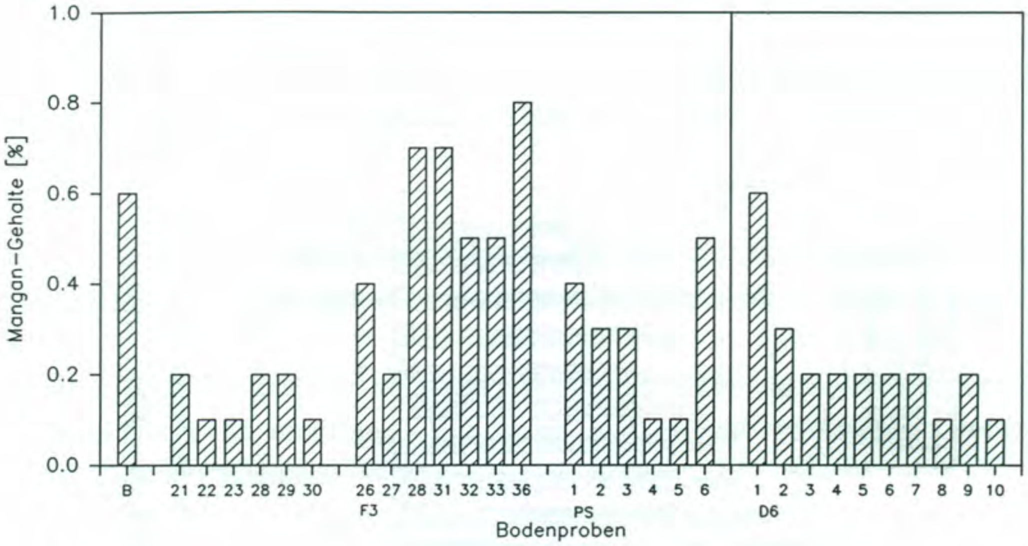


Abb. 2:
Mangan-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

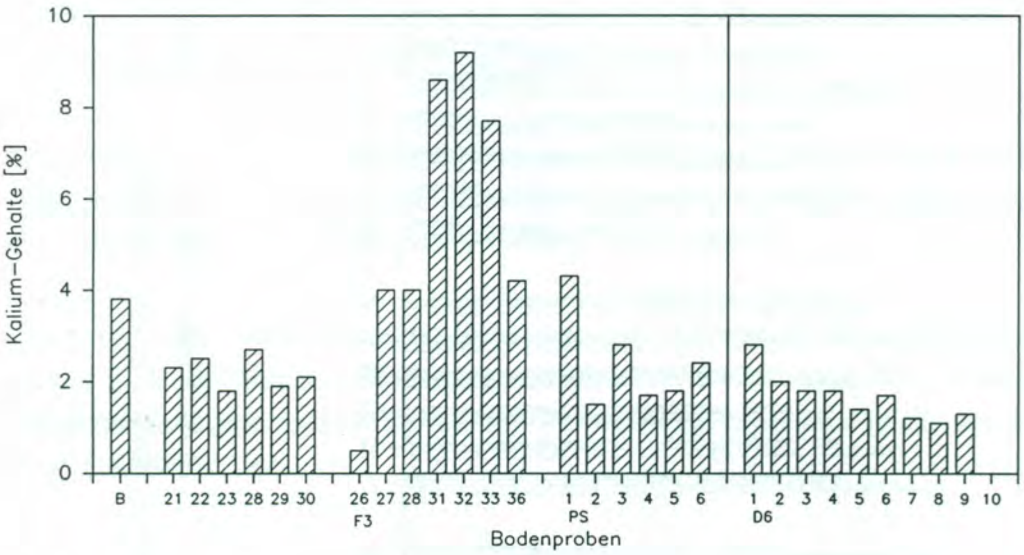


Abb. 3:
Kalium-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

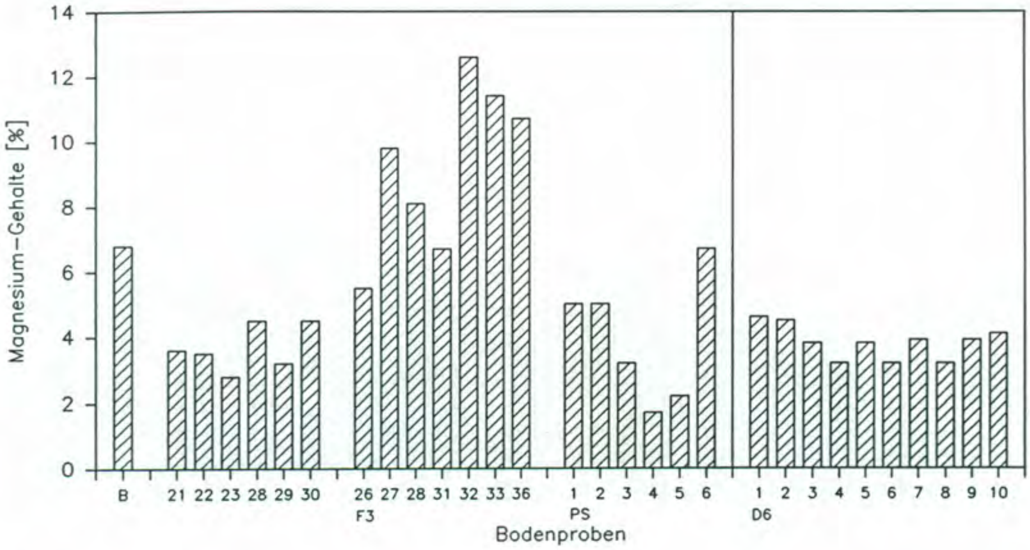


Abb. 4:
Magnesium-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

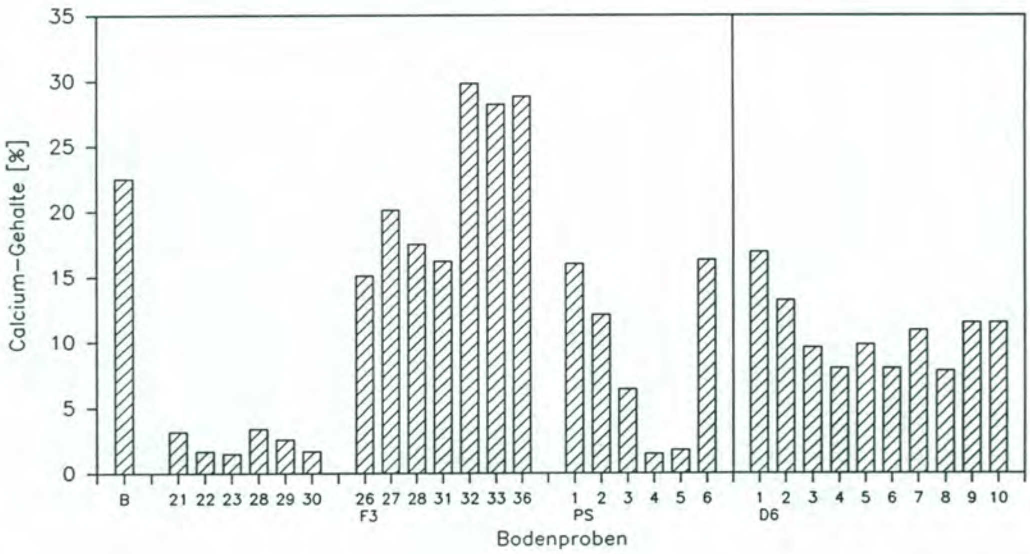


Abb. 5:
Calcium-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

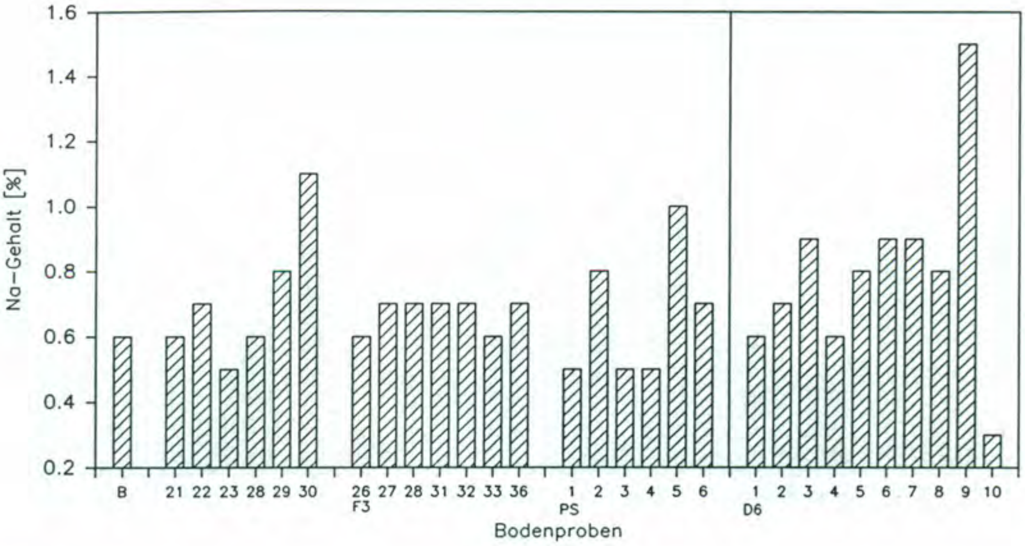


Abb. 6:
Natrium-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

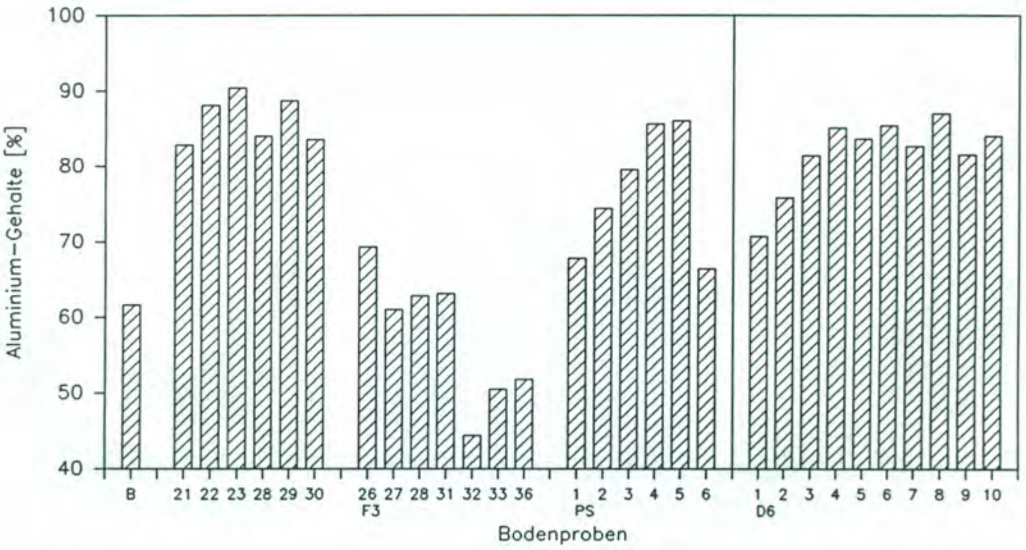


Abb. 7:
Aluminium-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

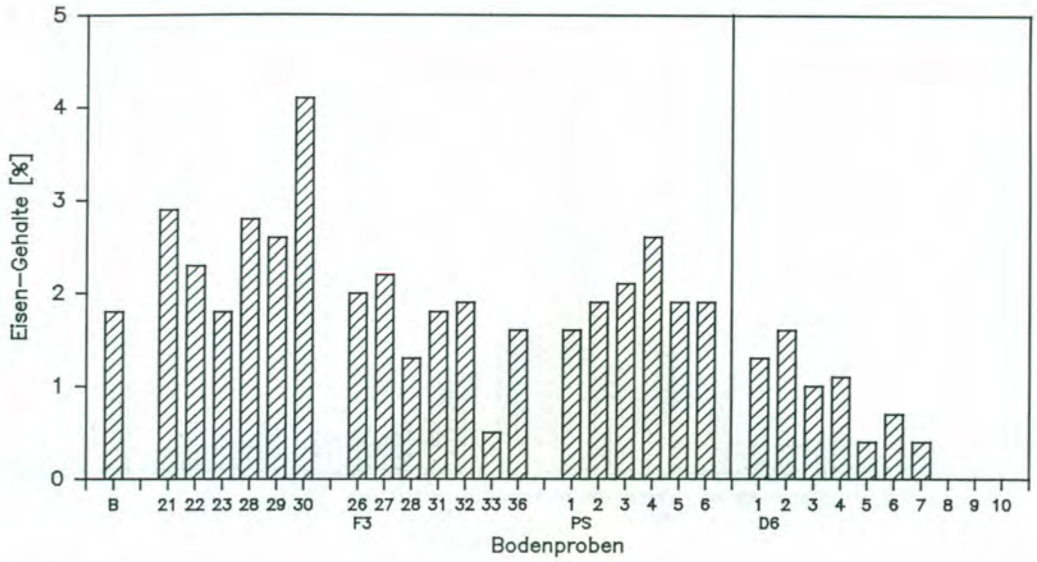


Abb. 8:
Eisen-Gehalte der Bodenproben (AKe-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

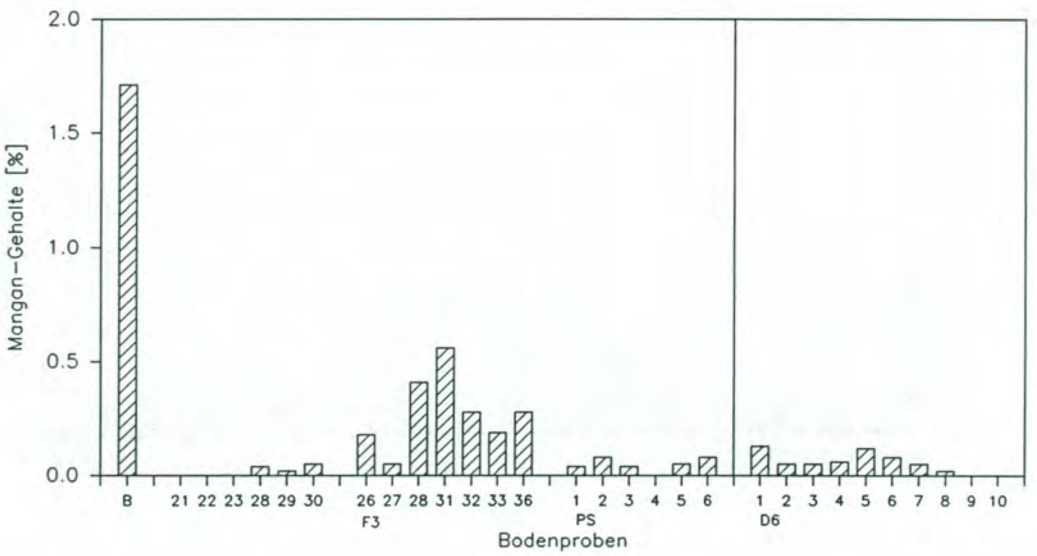
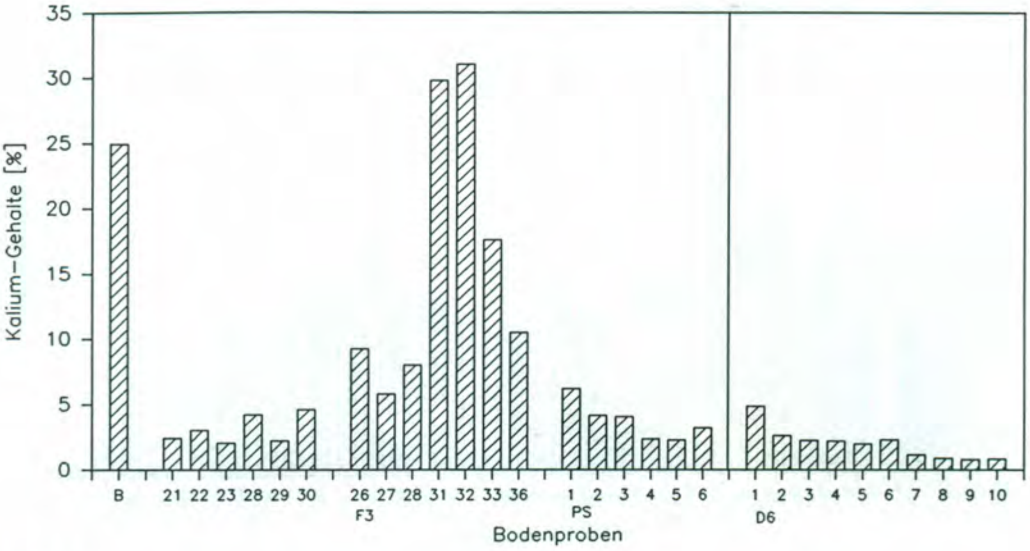


Abb. 9:
Mangan-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm



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Kalium-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

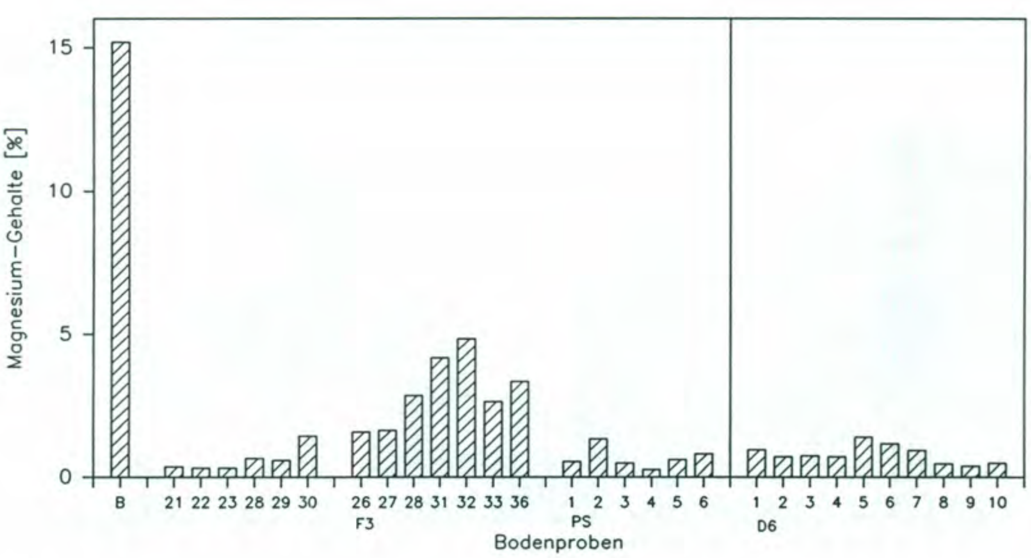

Abb. 11:
Magnesium-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

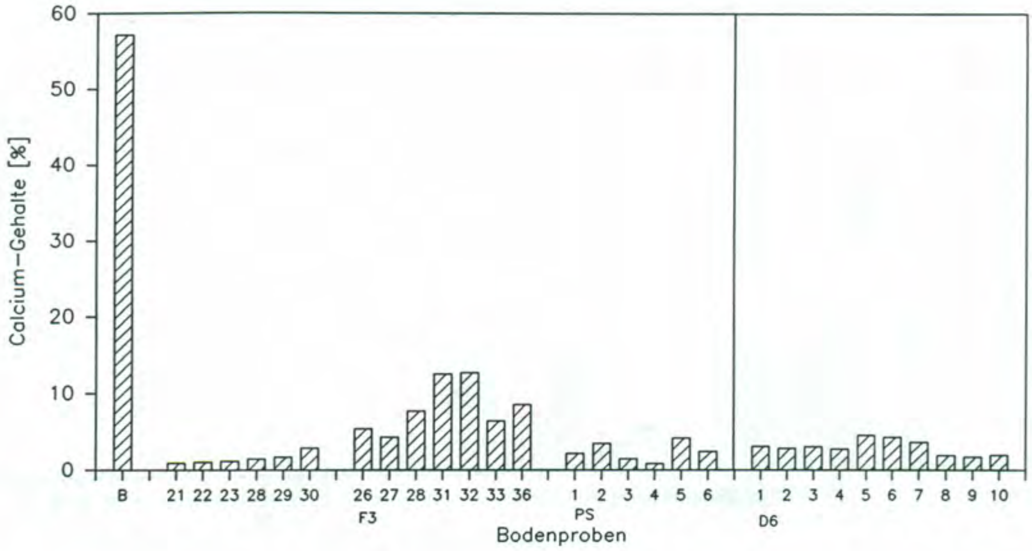

Abb. 12:
Calcium-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

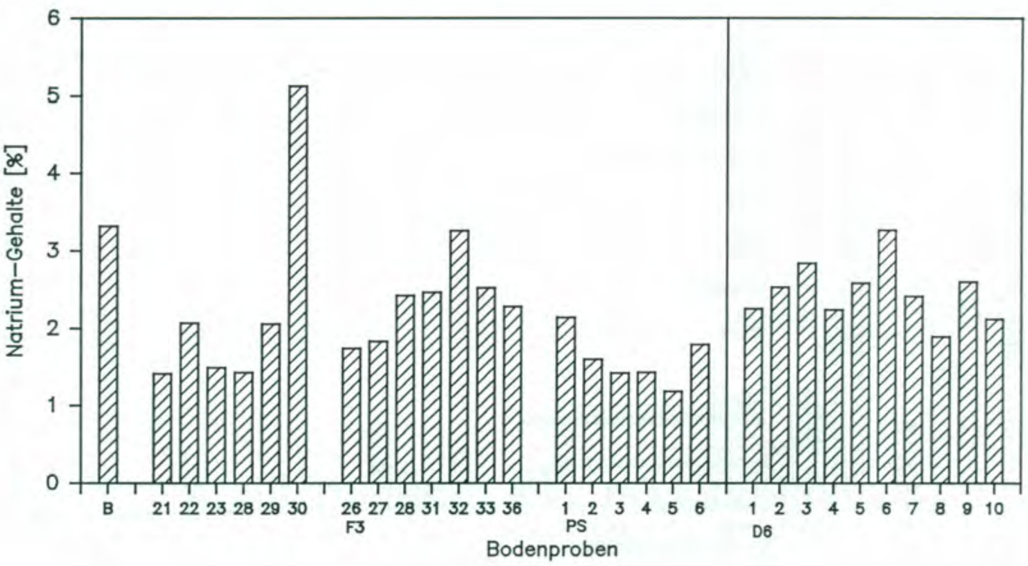

Abb. 13:
Natrium-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

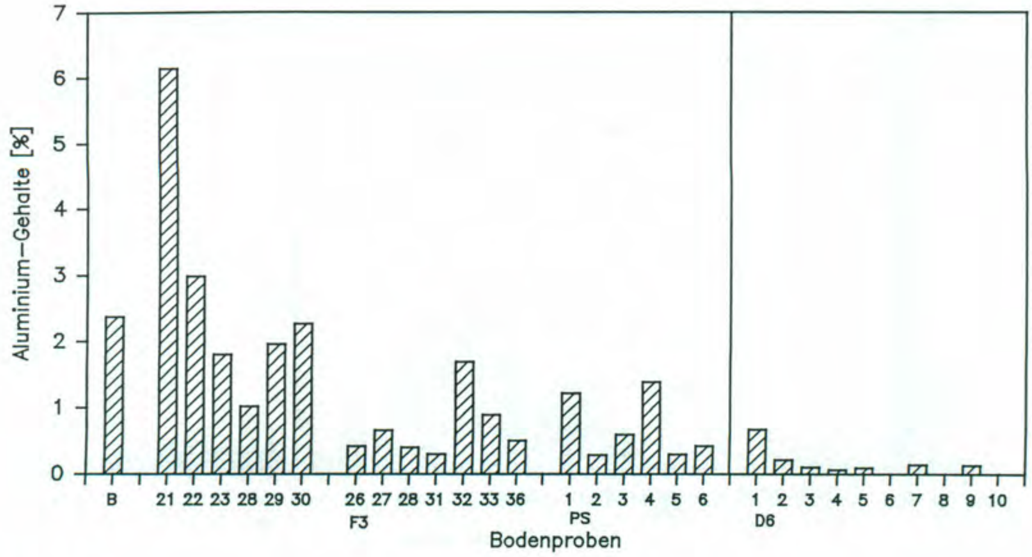

Abb. 14:

Aluminium-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

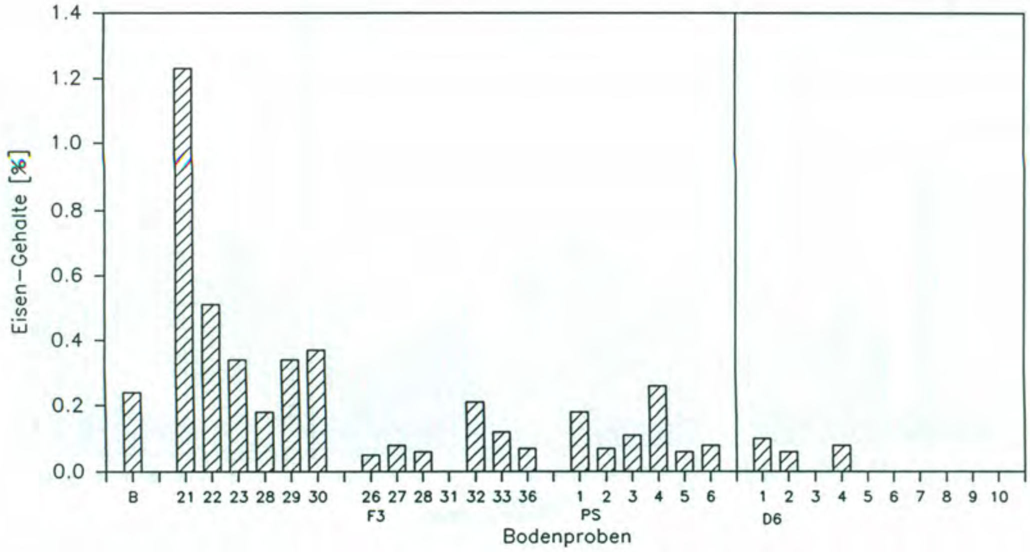

Abb. 15:

Eisen-Gehalte der Bodenproben (GBL-Analysen); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

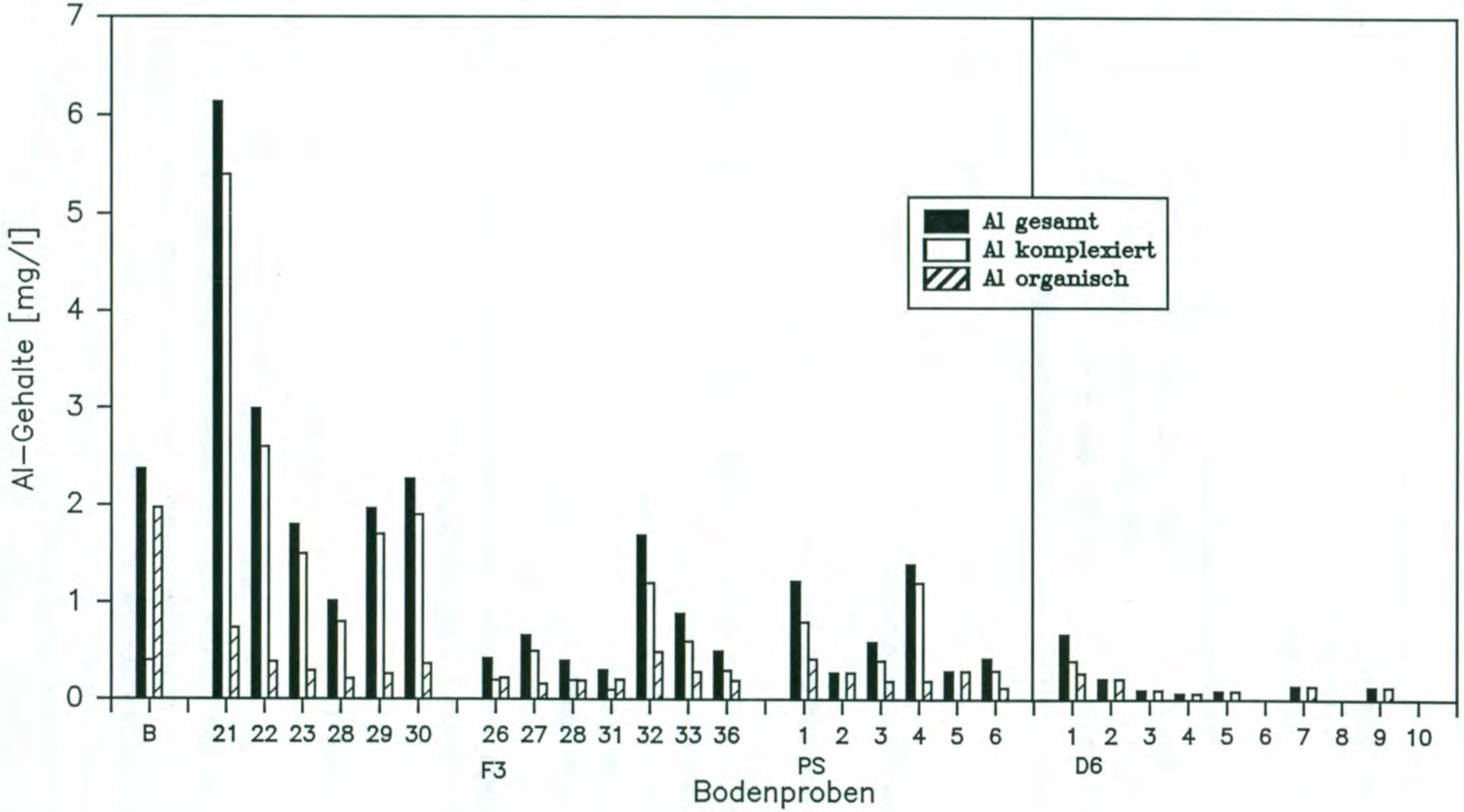

Abb. 16:

Gehalte der verschiedenen Aluminium-Arten (Al-Speziierung); B = Beutel; 21-30 = vor der Brandrodung; F3 = direkt nach dem Brennen; PS = 6 Monate nach dem Brennen; D6 = 6 Monate nach dem Brennen und Bodentiefen 0-100cm

Leitlinien für das Management der Versuchsfläche

L. Gasparotto & H. Preisinger

1 Definition

Die Versuchsfläche besteht aus der Anbaufläche (90 Parzellen in 5 Blöcken), einer 1 ha großen Sekundärwald-Referenzfläche, randlichen Bracheflächen sowie aus dem angrenzenden Sekundär- und Primärwald. Die nachfolgenden Leitlinien ergeben sich aus dem wichtigsten erklärten Versuchsziel, der Erprobung einer nachhaltigen und erfolgreichen Wieder-Nutzung einer aufgegebenen Plantage.

2 Anbaufläche

2.1 1-ha-Sekundärwald und System 5

Die Bracheparzellen und der als Referenzfläche dienende Sekundärwald bleiben ohne jegliches Management und ohne Eingriffe.

2.2 Systeme 6, 7, 8 und 9

Die Monokulturparzellen erhalten ein konventionelles Management, welches in das Ermessen der mitarbeitenden Agrartechniker gestellt ist.

2.3 Systeme 1, 2 und 3

Die Baumscheiben der ausdauernden Pflanzenarten in den Parzellen werden von Wildpflanzenwuchs mit Hacke und Buschmesser freigehalten. *Dabei darf die Bodenoberfläche nicht aufgerissen werden, um die hier befindlichen Wurzeln der Nutzpflanzen nicht zu beschädigen.*

Alle Nutzpflanzen werden von den rankenden Trieben des Bodendeckers *Pueraria phaseoloides* und von anderen rankenden Wildpflanzen laufend freigeschnitten. Soweit notwendig werden auch die kurzlebigen Kulturen von Wildpflanzen freigehalten.

2.4 System 4

In dem Agroforst-System wird in den Reihen von Zeit zu Zeit der oberirdische Wildpflanzenwuchs entfernt. Zwischen den Reihen wird (insbesondere baumförmiger) Wildpflanzenwuchs zugelassen. Erst wenn die Sekundärvegetation die Nutzpflanzen beginnt zu überwachsen, wird sie um 1m zurückgeschnitten (nicht jedoch entfernt).

Das Pflanzenmaterial wird, wenn notwendig, zerschnitten und verbleibt in den Reihen.

3 Flächenränder und Wegesystem

3.1 Brachestreifen

Eingriffe in die aufwachsende Vegetation der Brachestreifen zwischen Parzellen und zwischen Parzellen und Wegen unterbleiben bis auf weiteres.

3.2 Angrenzender Primär- und Sekundärwald

Die an die Versuchsfläche angrenzenden Primär- und Sekundärwald-Streifen sind ein wichtiger Teil des Versuchs. Sie dürfen deshalb nicht gestört oder zerstört werden. Das Freischlagen von Wegen und das Roden und der Abtransport von Bäumen müssen unterbunden werden. Im Randbereich des Sekundärwaldes darf in begrenztem Ausmaß Pflanzenmaterial geschnitten und entnommen werden, welches für die Plantage oder die Arbeiten dort benötigt wird (z.B. Schneiden von Markierungsstöcken und von Blättern für den Bau von Unterständen).

3.3 Wegesystem

Die Wege sind mit der nötigen Umsicht zu befahren, um Schäden (wie Schlaglöcher) und ihre Folgewirkungen (Bodenerosion) soweit wie möglich zu vermeiden. Außerhalb der Wege dürfen Motorfahrzeuge nicht benutzt werden. Das Umfahren von Schlaglöchern durch Ausweichen in die randliche Vegetation ist zu vermeiden, weil dadurch die vegetationsfreien Flächen und damit die Gefahr der Bodenerosion vergrößert werden. Große Schlaglöcher sind deshalb nach ihrer Entstehung umgehend zu reparieren. Es sind weitere Maßnahmen zu erarbeiten, um die Bodenerosion verhindern. Diese geht vor allem von dem bestehenden und derzeit stark befahrenen Wegesystem aus.

Manejo das culturas e da área experimental

Jeferson L.V. de Macêdo, Cley D.M. Nunes & Petra Schmidt

Zusammenfassung:

Management der Kulturen und der Versuchsfläche
Nachfolgend werden die bisher durchgeführten Kultur- und Management-Maßnahmen, in der Pflanzenanzucht und auf der Experimentalfläche, für die verschiedenen Nutzpflanzenarten getrennt in chronologischer Reihenfolge dargestellt. Diese Dokumentation wird wird von Zeit zu Zeit aktualisiert und dient als Nachschlagewerk für alle Projektmitarbeiter.

1 Introdução

A área onde se encontra implantado o ensaio do Projeto SHIFT, denominada "Área das 17 hectares", no fim da década de 1970, teve sua vegetação primária derrubada manualmente e posteriormente queimada. Entretanto, esta última operação não alcançou os resultados esperados, ficando muitos restos vegetais sobre a área. Por volta de 1980, época em que se implantou muitos projetos na Área Experimental do ex-CNPSD, a "Área das 17" foi submetida a um novo preparo de área, só que, dessa vez, mecanizado. Com auxílio de um trator de esteiras, retirou-se toda vegetação existente e, com esta, a camada superficial do solo. No local onde estão alocados os blocos A e B, principalmente o bloco A, foram conduzidos experimentos de competição de clones de seringueira. Ressalta-se que esses experimentos foram regularmente adubados durante os cinco primeiros anos de condução (aproximadamente até 1985). No restante da área, onde estão alocados os blocos C, D e E, foram conduzidos vários experimentos de clones primários e cruzamentos. Convém salientar, que estes experimentos foram implantados em pequenas áreas, com diferentes idades e bem dispersos uns dos outros.

Em agosto de 1992, efetuou-se um levantamento planimétrico para calcular a superfície real das "17 hectares". No período de agosto a outubro do mesmo ano, a capoeira e os experimentos de seringueira foram manualmente derrubados e queimados.

Em janeiro de 1993, efetuou-se um levantamento planialtimétrico mais detalhado, objetivando fornecer subsídios para a alocação dos blocos e das parcelas na área experimental. No período de fevereiro a junho de 1993, implantou-se o experimento.

2 Metodologia

O experimento, com 16,6 ha, encontra-se instalado numa área de terra firme, situada no Campo Experimental do CPAA/EMBRAPA, composto pelos seguintes sistemas de plantio (veja também *Lieberei et al.*):

Sistema 1:
Cultivo intensivo formado por seringueira, cupuaçu, mamão e pupunha. Nas entrelinhas, semeou-se puerária para cobertura do solo.

Sistema 2:
Composto por urucum, castanha-do-Brasil, cupuaçu e pupunha. Nas entrelinhas, plantou-se mandioca e, posteriormente, puerária.

Sistema 3:
Composto por seringueira, cupuaçu, paricá, côco e laranja. Nas entrelinhas, plantou-se alternadamente feijão caupi, milho e mandioca e, posteriormente, puerária.

Sistema 4:
Dentre os sistemas testados, é o mais extensivo. As espécies plantadas, em sua maioria, destinam-se à produção de madeira. É composto de seringueira, mogno, andiroba e paricá. Nas entrelinhas, está se deixando estabelecer a vegetação secundária.

Sistema 5:
Sem espécies de interesse econômico. Neste sistema, está se deixando formar a vegetação secundária, ou seja, uma área de pousio.

Sistema 6:
Monocultivo de seringueira. Nas entrelinhas, semeou-se puerária.

Sistema 7:
Monocultivo de cupuaçuzeiro. Nas entrelinhas, semeou-se puerária.

Sistema 8:
Monocultivo de pupunha para produção de palmito.

Sistema 9:
Monocultivo de laranja Pera Rio.

As adubações adotadas para os quatro sistemas de policultivo (1 a 4), constituem-se de 30% e 100% da dosagem recomendada para as respectivas espécies utilizadas. Nesses mesmos sistemas, parte das plantas foram inoculadas com fungos micorrízicos.

Nos monocultivos (sistema 6 a 9) a adubação é feita com 100% da dosagem recomendada para cada espécie.

O delineamento adotado é o de blocos ao acaso, com 18 tratamentos e 5 repetições. Cada parcela é composta de uma área de 1536m².

3 Manejo de cada espécie no experimento

3.1 Andiroba

As sementes "pré-germinadas" foram colhidas num plantio nativo da Área Experimental do CPAA/EMBRAPA.

Descrição das Atividades	Data
PREPARO DAS MUDAS	
. Preparo e composição do substrato	
- Terriço + areia (15%) + 5% de *Glomus etunicatum* T6	novembro 92
OBS: As sementes foram plantadas em sacos plásticos de 10 l.	
. Viveiro	
- Com cobertura de sombrite	dezembro 92
LOCAL DEFINITIVO	
. Marcação e abertura das covas	janeiro 93
. Plantio (bloco A para bloco E)	meados de fevereiro 93
. Adubação (ver plano de adubação)	
- Adubação na cova	início de fevereiro 93
- Adubação de cobertura: 1ª	19.03.93
2ª	07.12.93
. Tratos culturais	
- Coroamento: 1°	maio 93
2°	agosto 93
3°	novembro 93
- Replantio: 1°	17.05.93
2°	01.11.93
. Controle fitossanitário	
- Aplicação de sulfato de cobre no colo da planta (controlar fungo desconhecido)	início de maio 93

Descrição das Atividades	Data

3.2 Castanha-do-Brasil

As sementes "pre-germinadas" foram adquiridas na Fazenda Aruanã, no Município de Itacoatiara.

PREPARO DAS MUDAS

. Preparo e composição do substrato	08 a 12.06.92
- Terriço + areia (15%) para enchimento de sacos de 10 l. Os fungos micorrízicos utilizados foram:	
* *Glomus etunicatum* 329 (13%)	
* *G. etunicatum* T6 (30%)	
* *G. intraradices* 208 (13%)	
* *G. intraradices* 267 (22%)	
* *G. manihotis* C11 (22%)	
Obs: Adicionou-se 5% dessa mistura a uma parte do substrato, o qual foi utilizado para preencher a parte superior do saco (3 l).	
. Semeio das sementes pré-germinadas	12.06.92
. Replantio	03.07.92
. Viveiro	
- As mudas foram acondicionadas no viveiro coberto com sombrite.	
. Tratos Culturais	
- Adubação foliar com Ouro Verde	final de novembro 92
Obs: O operação realizada em intervalos de 14 dias.	
- Adubação com 10g de SFT/planta	final de dezembro 92
- Aumento da distância entre plantas	Início de janeiro 92
Obs: Nessa ocasião as mudas foram transportadas para outro viveiro coberto com sombrite	
. Avaliação no viveiro	
- Altura e número de folhas	10.12.92
Obs: Foram Medidas 100 plantas ao acaso de cada tratamento	
- Altura e número de folhas	10.02.93
Obs: Medidas todas as plantas por ocasião do plantio	

LOCAL DEFINITIVO

. Marcação e abertura das covas	janeiro 93
. Plantio (bloco A para bloco E)	10.02.93
. Adubação (ver plano de adubação)	início de fevereiro 93
- Adubação na cova	
- Adubação de cobertura: 1ª	19.03.93
2ª	07.12.93

Descrição das Atividades	Data
- Poda de formação: 1ª	19.03.93
2ª	19.05.93
3ª	23.07.93

3.5 Laranja

A variedade utilizada foi Pera Rio.

. Aquisição das mudas	15.03.93
LOCAL DEFINITIVO	
. Marcação e abertura das covas	janeiro 93
. Plantio	17-19.03.93
Obs: A inoculação com fungo micorrízico foi feita na ocasião do plantio, utilizando-se o *Glomus etunicatum* D13 na base de 3 l/planta.	
. Adubação (ver plantio de adubação)	
- Adubação de cova	10-12.03.97
- Adubação de cobertura: 1ª	01.06.93
2ª	09.12.93
. Tratos culturais	
- Coroamento: 1°	maio 93
2°	agosto 93
3°	novembro 93
- Replantio: 1°	17.05.93
2°	11.10.93
- Desbrota	uma vez/mês
. Controle fitossanitário	
- Aplicação de inseticida biológico (*Aschersonia* sp) para controlar cochonilhas (1g/1 l de água).	não registrada
- Aplicação de Tamaron (inseticida organo-fosforado sistêmico) para controle de colchonilhas. Utilizou-se 1 ml do produto/1 l de água + espalhante adesivo (10ml/20 l de água).	11.01.94

3.6 Mamão

A variedade utilizada foi "sunrise" solo (mamão hawai) linhagem ISS 72.

PREPARO DAS MUDAS	
. Preparo e composição do substrato	29.01.93
- Terriço + areia + esterco (4:2:1) + 1% de calcário dolomítico + 5% de *Glomus etunicatum* D13.	
. Semeadura	03.02.93
Obs: No preparo das mudas foram utilizados copos plásticos de 500 ml. Foram semeadas 3 sementes/copo a uma profundidade de 1-2cm.	
. Resemeadura	26.02.93
Obs: Semeou-se 1 semente nos copos onde não houve germinação	

Descrição das Atividades	Data
. Viveiro	
- 1° estágio (viveiro com cobertura de palhas)	até 24.02.93
- 2° estágio (estufa com cobertura de vidros)	de 25.02.93 até o plantio
. Tratos culturais	
- Desbaste	16.03.93
- Aumento da distância entre plantas	24.03.93
. Avaliação no viveiro	15-19.04.93
Obs: Toda vez que se efetuava o plantio de um bloco, eram medidas 40 plantas ao acaso de cada tratamento.	
LOCAL DEFINITIVO	
. Marcação e abertura das covas	fim de março 93
. Plantio (bloco A para bloco E)	15-19.04.93
. Adubação (ver plano de adubação)	
- Adubação de cova	05-14.04.93
- Adubação química de cobertura: 1ª	02-04.06.93
2ª	30.11.93
- Adubação orgânica: 1ª	07-11.06.93
2ª	03-07.01.94
. Tratos culturais	
- Coroamento: 1°	maio 93
2°	agosto 93
3°	novembro 93
- Replantio: 1°	25.05.93

3.7 Mandioca no sistema 2

As cultivares utilizadas foram: IM 157 (vinagre) e IM 226 (pão), ambas procedendes do Jardim Clonal do CPAA/EMBRAPA. Foram inoculadas com fungo micorrízico (*Glomus etunicatum* D13) na base de 300ml/planta, por ocasião do plantio. O espaçamento utilizado foi de 1,0m x 1,20m, perfazendo um total de 100 plantas/parcela.

LOCAL DEFINITIVO

. Preparo da área	
- Capina	25.07 a 10.07.93
. Plantio (bloco A para bloco E)	12 a 28.07.93
Obs: Por insuficiência de material da cultura IM 157, todas as parcelas do bloco B e as parcelas com micorríza do bloco C foram plantadas com IM 226.	
. Adubação (ver plano de adubação)	
- Adubação de cobertura	não registrada
. Tratos culturais	
- Capina: 1ª	31.05 a 07.06.93
2ª*	29.09 a 08.10.93
- Retirada da puerária das parcelas: 1ª*	09 a 16.07.93
2ª*	16 a 20.08.93
- Coleta manual e eliminação de mandarová*	meados de maio

* Operações realizadas em conjunto com a mandioca do sistema 3.

Descrição das Atividades	Data
Obs: Do 1° ao 3° mês, foram feitas coletas semanais. Do 4° ao 5° mês, foram feitas coletas quinzenais	até final de setembro 93

3.8 Mandioca no sistema 3

As cultivares utilizadas foram: IM 116 e IM 226, ambas procedentes do jardim clonal do CPAA/EMBRAPA. Foram inoculadas com fungo micorrízico (*Glomus etunicatum* D13), na base de 300ml/planta, por ocasião do plantio. O espaçamento utilizado foi de 1,0m x 1,20m, perfazendo um total de 300 plantas/parcela.

LOCAL DEFINITIVO

. Preparo da área	
- Capina	19 a 24.09.93
. Plantio (bloco E para bloco A)	29.04 a 21.05.93
Obs: Cada cultivar foi plantada em uma faixa. A cultivar IM 226 foi plantada no lado direito e a cultivar IM 116, plantada no lado esquerdo da parcela. Nas parcelas A7 e A12, foi plantada somente a cultivar IM 226 em ambos os lados.	
. Adubação (ver plano de adubação)	
Adubação de cobertura	não registrada
. Tratos culturais	
- Capina: 1ª	07 a 15.06.93
2ª	20.09 a 08.10.93
- Retirada da puerária das parcelas: 1ª	09 a 16.07.93
2ª	16 a 20.08.93
- Coleta manual e eliminação de mandarová	início de junho até o final de setembro 93
Obs: Idem mandioca no sistema 2	

3.9 Milho

A cultivar utilizada foi a BR 5110. As sementes foram adquiridas no CPAA/EMBRAPA. O espaçamento utilizado foi de 1,0m x 0,5m.

LOCAL DEFINITIVO

. Preparo da área	
- Capina	19 a 24.04.93
- Calagem	27 a 30.04.93
Obs: Aplicou-se 3,5 ton de calcário dolomítico com 80% de PRNT/ha.	
. Plantio (bloco E para bloco A)	28.07 a 23.05.93
. Adubação (ver plano de adubação)	
- Adubação de cobertura: 1ª	17 a 18.05.93
2ª	25.05.93
. Tratamento fitossanitário	
- Aplicação de Carbaryl (1 ml do produto/1 l de água) para controlar lagarta do cartucho	não registrada

Descrição das Atividades	Data
. Colheita e coleta de dados	30.08 a 01.09.93
. Debulha manual e coleta de dados	08 a 13.09.93

3.10 Mogno

As sementes foram coletadas em plantios silvestres da Área Experimental do CPAA/EMBRAPA.

PREPARO DAS MUDAS

. Semeio	09.07.92
Obs: As sementes foram colocadas para germinar em areia + serragem (1:1).	
. Preparo e composição do subtrato - Terriço + areia (15%) para enchimento de sacos de 10 l. Os fungos micorrízicos utilizados foram: * *Glomus etunicatum* T6 (38%) * *G. intraradices* 267 (29%) * *G. manihotis* (24%) * *Symbionta* (9%)	final de maio 92
Obs: Adicionou-se 5% dessa mistura a uma parte do substrato, o qual foi utilizado para preencher a parte superior do saco (3 l).	
. Transplantio para os sacos plásticos de 10 l	05.08.92
. Viveiro - As mudas foram acondicionadas em casa de vegetação.	
. Tratos culturais	
- Adubação com MAP + Ouro Verde	final de nov. 92
- Aumento da distância entre plantas	final de nov. 92
. Avaliação no viveiro	
- Altura e número de folhas	06.01.93
Obs: Medidas 18 plantas ao acaso	
- Altura e número de folhas	01.02.93
Obs: Medidas 24 e 47 plantas dos tratamentos sem micorrizas e com micorrízas, respectivamente	

LOCAL DEFINITIVO

. Marcação e abertura das covas	janeiro 93
. Plantio (bloco A para bloco E)	meados de fev.93
. Adubação (ver plano de adubação)	
- Adubação de cova	início de fev.93
- Adubação de cobertura 1ª	19.03.93
2ª	07.12.93
. Tratos culturais	
- Coroamento: 1°	maio 93
2°	agosto 93
3°	novembro 93

Descrição das Atividades	Data
- Replantio: 1°	17.05.93
2°	01.11.93
. Controle fitossanitário	
- Aplicação de sulfato de cobre no colo da planta.	início de maio 93.

3.11 Paricá

As sementes foram provenientes de plantios nativos da região Leste do Estado do Amazonas.

PREPARO DAS MUDAS	
. Semeio	
Obs: As sementes foram colocadas para germinar em areia + serragem (1:1)	
. Preparo e composição do substrato	final de maio 92
- Idem MOGNO	
. Semeio das plântulas	
- Tratamento sem micorrízas	05.06.92
- Tratamento com micorrízas	23.06.92
. Transplantio em sacos plásticos de 10 l	
- Tratamento sem micorrízas	19.06.92
- Tratamento com micorrízas	19.07.92
. Viveiro	
- 1° estágio (casa de vegetação)	até meados de dezembro 92
- 2° estágio (viveiro à céu aberto-maior distância entre plantas)	meados de dezembro 92 até o plantio
. Tratos Culturais	
- Adubação foliar com MAP + ouro verde	final de novembro 92
Obs: Operação realizada em intervalos de 14 dias.	
. Avaliação no vieiro	
- Altura e número de folhas	10.06.92
Obs: Medidas 70 plantas de cada tratamento	
- Altura e número de folhas	01.02.93
Obs: Medidas 75 e 112 plantas dos tratamentos sem e com micorrízas, respectivamente.	
LOCAL DEFINITIVO	
. Marcação e abertura das covas	janeiro 93
. Plantio (bloco A para bloco E)	meados de fev. 93
. Adubação (ver plano de adubação)	
- Adubação de cova	início de fev. 93
- Adubação de cobertura: 1ª	19.03.93
2ª	07.12.93

Descrição das Atividades	Data
. Tratos Culturais	
- Coroamento: 1°	maio 93
2°	agosto 93
3°	novembro 93
- Replantio	17.05.93
- Tutoramento	29.07.93
. Controle Fitossanitário	
- Aplicação de sulfato de cobre no colo da planta para controlar fungo desconhecido	inicio maio 93

3.12 Pupunha

PREPARO DAS MUDAS

. Preparo e composição do substrato	julho 93
- Terriço + areia (15%) + 5% de *Glomus etunicatum* D13.	
Obs: Esse substrato foi utlizado para o enchimento de 1/3 da parte inferior dos sacos 10 l.	
. Transplantio das mudas para sacos plásticos de 10 l.	20.10 a 30.11.92
. Viveiro	
- As mudas foram acondicionadas em viveiro à céu aberto	
. Tratos Culturais	
- Aplicação de MAP + ouro verde	Final de nov. 92
Obs: Operação realizada em intervalos de 14 dias.	
- Adubação com 10g de SFT/planta	06.01.93
. Avaliação no viveiro	06.01 a 28.02.93
- Altura das plantas	
Obs: Medidas 242 plantas ao acaso de cada tratamento	

LOCAL DEFINITIVO

. Marcação e abertura das covas	janeiro 93
. Plantio (bloco A para bloco E)	final de janeiro até meados de março de 93
. Adubação (ver plano de adubação)	
- Adubação de cova	final de fev.93
- Adubação de cobertura: 1ª	meados até fim de maio 93
2ª	01.12.93
. Tratos Culturais	
- Coroamento: 1ª	maio 93
2ª	agosto 93
3ª	novembro 93
- Replantio	17.05.93
- Amontoa	02.07.93

Descrição das Atividades	Data
- Desbrota	mensal
- Decaptação, enxertia de copa e aplicação de piche: 1ª	novembro 93
2ª	janeiro 94

3.14 Urucum

As sementes foram provenientes de plantios da Costa de Iranduba.

PREPARO DAS MUDAS

. Preparo e composição do substrato	30.06.92
- Terriço + areia (15%). Os fungos micorrízicos utilizados foram.	
* *G. etunicatum* 329 (5%)	
* *G. etunicatum* T6 (18%)	
* *G. intraradices* 208 (3%)	
* *G. intraradices* 267 (16%)	
* *G. manihotis* C11 (58%)	
Obs: Utilizou-se 7% desta mistura no substrato, para enchimento de sacos de 2 l.	
. Semeadura	03 a 07.07.92
Obs: Utilizou-se sacos de 2 l para produção inicial das mudas.	
. Viveiro	
- 1° estágio (casa de vegetação)	até meados de novembro 92
2° estágio (viveiro a céu aberto)	a partir de meados de nov. 92
. Trados culturais no viveiro	
- Transplantio das mudas para sacos plásticos de 10 l	final de out. 92
- Adubação foliar com MAP + Ouro verde	novembro 92
- Aplicação de 10g de SFT/planta	dezembro 92
- Aplicação de Benomil (50g/100 l)	16.12.92
. Avaliação no viveiro	
- Altura e número de folhas	10.12.92
Obs: Medidas 150 plantas ao acaso de cada tratamento.	
- Análise foliar	15.01.92

LOCAL DEFINITIVO

. Marcação e abertura das covas	janeiro 93
. Plantio (bloco A para bloco E)	meados de março 93
. Adubação (ver plano de adubação)	
- Adubação de cova	final de fevereiro 93
- Adubação de cobertura: 1ª	31.05.93
2ª	09.12.93

Descrição das Atividades	Data
. Tratos culturais	
- Coroamento 1ª	maio 93
2ª	agosto 93
3ª	novembro 93
- Replantio	17.05.93
- Poda de condução (eliminação do broto das plantas a uma altura de 75 cm)	01.04.93
- Poda de formação (eliminação dos ramos do tronco até a altura de 40cm do solo)	30.08.93

4. Plano de adubação

4.1 Culturas annuais

Adubação / Culturas	Adubação de Plantio (Kg/ha) 100%	30%	Adubação Cobertura (Kg/ha) 100%	30%
MANDIOCA	Plantio atrasado-não houve possibilidade de adubar.		89 kg SFT 75 Kg KCl	27 Kg SFT 22,5 Kg KCl
MILHO	3500 Kg Calcário 50 Kg SFT 100 Kg KCl	3500 Kg Calcário 15 Kg SFT 30 Kg KCl	66,6kg Uréia	20kg Uréia
FEIJÃO CAUPI	3500 Kg Calcário 50 Kg SFT 100 Kg KCl	3500 Kg Calcário 15 Kg SFT 30 Kg KCl	-	-

(Plano de adubação)

4.2 Culturas perennes

Culturas \ Adubações	Cova (g/pl) 100%	Cova (g/pl) 30%	1ª Adubação de cobertura 100%	1ª Adubação de cobertura 30%	2ª Adubação de cobertura 100%	2ª Adubação de cobertura 30%
SERINGUEIRA	500g calcário 155g SFT 100g KCl	500g calcário 47g SFT 30g KCl	65g Uréia	20g Uréia	50g Uréia 100g SFT 50g KCl 50g $MgSO_4$ 20g FTE BR8	15g Uréia 30g SFT 15g KCl 15g $MgSO_4$ 6g FTE BR8
CASTANHA	Idem seringueira	Idem seringueira	Idem seringueira	Idem seringueira	Idem seringueira	Idem seringueira
PARICÁ	Idem seringueira	Idem seringueira	Idem seringueira	Idem seringueira	Idem seringueira	Idem seringueira
MOGNO	Idem seringueira	-	Idem seringueira	-	Idem seringueira	-
ANDIROBA	Idem seringueira	-	Idem seringueira	-	Idem seringueira	-
PUPUNHA	200g calcário 111g SFT 37g Uréia 56g KCl	200g calcário 33g SFT 11g Uréia 17g KCl	74g Uréia 112g KCl	22g Uréia 34g KCl	52g Uréia 21g SFT 17g KCl 1g Bórax 1g Zincop 101	15.6g Uréia 6.3g SFT 5.1g KCl 0.3g Bórax 0.3g Zincop 101
CUPUAÇU	500g Cálcio 100g SFT 30g KCl 5g Bórax	500g Cálcio 30g SFT 9g KCl 1.5g Bórax	44g Uréia 60g KCl	14g Uréia 18g KCl	27g Uréia 27g SFT 20g KCl 16g $MgSO_4$	8g Uréia 8g SFT 6g KCl 4.5g Mg SO_4
MAMÃO	1000g Calcário 155g SFT 111g Uréia 50g KCl 3 l esterco galinha	1000g Calcário 47g SFT 33g Uréia 15g KCl 0.9 l esterco galinha	130g Uréia 50g KCl 3 l esterco galinha	40g Uréia 15g KCl 0.9l esterco galinha	333g Uréia 178g SFT 100g KCl 10 l esterco galinha	99.9g Uréia 53.4g SFT 30g KCl 3 l esterco galinha
URUCUM	200g Calcário 16g KCl	200g Calcário 5g KCl	22g Uréia 67g SFT 16g KCl	7g Uréia 20g SFT 5g KCl	30g Uréia 90g SFT 80g KCl	9g Uréia 27g SFT 24g KCl
CÔCO	1000g Calcário 230g SFT 173g Uréia 173g Uréia	1000g Calcário 70g SFT 58g Uréia 58g Uréia	-	-	542g Uréia 118g SFT 407g KCl	163g Uréia 36g SFT 122g KCl
LARANJA	1000g Calcário 155g SFT 100g KCl 5 l esterco galinha	1000g Calcário 47g SFT 30g KCl 1.5 l esterco galinha	67g Uréia	20g Uréia	161g Uréia 172g SFT 80g KCl	48g Uréia 51g SFT 24g KCl

O plantio de citrus foi feito no final de março de 1993, e o de cupuaçu, em fevereiro de 1993. A primeira avaliação do crescimento de ambas culturas foi efetuada quatro meses após o plantio.

As plantas de cupuaçu apresentaram em média 75,1 cm de altura e 9,4 mm de diâmetro do caule. A média da altura e do diâmetro do caule, em cada sistema, foram: sistema 1: 74,3 cm e 9,3 mm, sistema 2: 74,7 cm e 9,5 mm, sistema 3: 77,3 cm e 9,6 mm; monocultivo: 71,9 cm e 8,8 mm e uma área contígua, em sistema sombreado (plantio em capoeira) 70,8 cm e 7,7 mm, respectivamente.

As plantas de citrus apresentaram média geral em altura e diâmetro do caule, acima de 10 cm do ponto de enxertia de 86,6 cm e 15,1 mm, respectivamente. Para a monocultura as médias foram 85,0cm e 14,3mm e no sistema de policultivo, de 87,0 cm e 15,3mm de altura e diâmetro, respectivamente.

Em virtude das duas culturas apresentarem crescimento muito lento e o espaço de tempo decorrido entre o plantio e a primeira avaliação de crescimento ser de apenas quatro meses, não foi efetuada análise estatística, visto que as diferenças eram muito pequenas.

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Problemas ecofisiológicos das culturas perenes incluidas nos sistemas de consórcio

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Zusammenfassung:

Ökophysiologische Probleme von Dauerkulturen unter Einschluß von Mischkultursystemen

Der Kenntnisstand zur Ökophysiologie der Nutzpflanzen, die auf der SHIFT-Experimentalfläche angebaut werden, verhält sich proportional zu ihrer ökonomischen Bedeutung. So liegen über Cocos, Citrus und den Kautschukbaum detaillierte Informationen vor. Dås Grundproblem des Kautschukbaum-Anbaus in Brasilien liegt darin, daß die für die maximale Produktivität des Kautschukbaumes erforderlichen Bedingungen - ganzjährige Feuchte - auch für den Erreger der bedeutendsten Krankheit dieses Baumes, der südamerikanischen Blattfallkrankheit, verursacht durch den Schadpilz Microcyclus ulei, günstig sind. Der Anbau in Regionen mit definierter Trockenzeit umgeht dieses Problem, jedoch wird die "Blutung", also der Ausfluß von Latex nach Verletzung des Baumes und damit die Produktivität, durch die Trockenheit vermindert. Durch Selektion von Klonen hoher Produktivität, die an die Trockenperiode angepaßt sind, wäre dieser Mangel zu beheben. In den dauerhaft feuchten Regionen Amazoniens dagegen ist die Forschung darauf ausgerichtet, auf Stämme eines produktiven Klones die Krone eines gegen den Schadpilz resistenten Klones zu okulieren. Dabei wird auch der Einfluß der Okulierung auf die Produktivität des Kautschukbaumes und die Qualität des Latex geprüft.

Der Anbau von Citrus in tropischen Breiten ist möglich, da aber die Dormanz induzierende tiefere Temperatur und geringere Feuchte fehlen, kommt es nicht wie in subtropischen Regionen zu einer simultanen und üppigen Blüte, sondern Blüten und Früchte finden sich über das ganze Jahr hin an einer Pflanze. Eine Kontrolle der Blütezeit in tropischen Regionen mit definierter Trockenzeit ist durch kontrollierte künstliche Bewässerung möglich. Der Zeitpunkt kann dabei so gewählt werden, daß die Fruchtreife in die folgende Trockenzeit fällt und damit eine bessere Qualität der Früchte erzielt werden kann. Eine weitere Möglichkeit der kontrollierten Blühinduktion besteht in der foliaren Applikation von Harnstoff.

Cocospflanzen sind auf gleichmäßige Feuchte über das ganze Jahr angewiesen. Darüber hinaus darf der Boden keinen zu hohen Tongehalt aufweisen, da in diesem Fall eine gute Durchwurzelung durch die dicken Wurzeln nicht möglich ist. Die Aufnahme von Wasser und Nährstoffen erfolgt dicht hinter der Wurzelhaube. In diesem Zusammenhang wären Untersuchungen zur Bedeutung einer Mykorrhizasymbiose von Interesse.

Cupuaçu ist eine Schattenpflanze, die im Vergleich zum Kakao toleranter gegenüber sauren Böden, hohen Aluminiumgehalten im Boden und geringer Nährstoffverfügbarkeit ist, was für den Anbau dieser Nutzpflanze auf Terra Firme Standorten spricht. Trockenheit beeinträchtigt die Fruchtbildung von Cupuaçu. Trockenheit bewirkt bei Pupunha den Fruchtfall vornehmlich junger Früchte. Urucum ist eine robuste Pflanze mit geringen Ansprüchen. Der hohe Gehalt an Carotinoiden in den Samen von Urucum ist bekannt. Sollten die Pflanzen auch in den Blättern hohe Gehalte aufweisen, wäre hiermit ein besserer Schutz vor photooxidativen Prozessen verbunden. Hierzu könnten interessante vergleichende Untersuchungen bei anderen Pflanzenarten angestellt werden.

1 Introdução

Entre as espécies perenes, excetuando-se as florestais, o projeto SHIFT de Manaus inclui seringueira (*Hevea brasiliensis* Muell. Arg.), cupuaçuzeiro (*Theobroma grandiflorum* Schum.), coqueiro (*Cocos nucifera* L.), laranjeira (*Citrus sinensis* Osbeck), urucuzeiro (*Bixa orellana* L.) e pupunheira (*Bactris gasipaes* H.B.K.). O nível de conhecimentos sobre a ecofisiologia dessas espécies é proporcional à sua importância econômica atual. Dados derivados de pesquisa com urucuzeiro, pupunheira e cupuaçuzeiro são escassos ou inexistentes, embora da experiência com o seu cultivo e das características ecológicas das áreas de ocorrência natural possam ser derivadas inferências orientadoras.

Quanto ao coqueiro, à laranjeira e à seringueira são encontradas informações detalhadas, respectivamente nas revisões de Murray (1977), Reuther (1977) e Moraes (1977), do livro editado por Alvim e Kozlowski (1977). As influências das relações hídricas sobre a produção de látex da seringueira foram revistas por Buttery e Boatmam (1976). Informações mais atualizadas sobre a fisiologia do látex e o efeito dos fatores ambientais sobre produtividade da seringueira são encontradas no livro editado por Auzac et al. (1989).

Este breve ensaio, limita-se à tentativa de formular propostas de temas de ecofisiologia, julgados importantes em relação com a produtividade agrícola das espécies acima mencionadas, na Amazônia. Solos e nutrição de plantas, e também a biologia do solo e a caracterização agro-climática da área do experimento, são abordados em outros capítulos deste relatório, cabendo aqui apenas algumas referências específicas para as espécies agrícolas perenes estudadas.

O texto mais extenso para seringueira reflete não apenas a complexidade do assunto, mas também a experiência do autor com esta cultura.

2 Seringueira

2.1 Relações hídricas

Os problemas de ecofisiologia da seringueira na Amazônia não podem ser dissociados dos graves problemas das enfermidades, particularmente do mal-das-folhas, causado pelo *Microcyclus ulei*. A produtividade máxima do látex é obtida em regiões com plena disponibilidade hídrica durante o ano todo, porém essa é também a condição favorável aos surtos epidêmicos do mal-das-folhas durante a troca anual da folhagem. Devido a esse impedimento, a heveicultura no Brasil expandiu-se nas regiões que contam com um período seco bem definido, incluindo partes da Amazônia com o clima do tipo Aw de Köppen (áreas de escape).

Como contribuição para seleção de clones mais adaptados às áreas de escape e tendo em conta os indícios mostrados por Ferrand (1944), de variabilidade clonal de resistência à seca, foram realizados estudos nesse sentido no Brasil (Rocha Neto 1979, Conceição 1983, Correa et al. 1986). Tais estudos abordaram, essencialmente, a eficiência do uso de água em plantas jovens, estando assim relacionados com a produtividade primária. Outros fatores podem, entretanto, interferir na produtividade de látex de clones com vigor excelente nas condições de áreas de escape.

É conhecida de muito tempo, a importância da disponibilidade hídrica para o escoamento do látex, com efeitos imediatos na sangria, porém reversíveis à curto prazo (Pakianathan et al. 1989). Na Índia, Raghanvedra et al. (1984a) encontraram evidências de alterações da composição das membranas celulares pelo estresse hídrico, com redução dos fosfolipidios neutros, que conferem maior estabilidade às membranas, essencial para a maior eficiência no escoamento e na regeneração (Jacob et al. 1988). Tal fato explica porquê os efeitos de défices hídricos severos estendem-se além do período seco e podem aumentar a ocorrência do secamento do painel, causado provavelmente pela coagulação "in situ" do látex (Chrestin 1984). Os clones com menor redução de produção na estação seca mantêm maior potencial osmótico no soro C (Raghavendra 1984b).

Para o propósito da seleção de clones melhor adaptados às áreas de escape há, portanto, necessidade de estudar não apenas as características das plantas ligadas à eficiência do uso da água, mas também parâmetros fisiológicos relacionados com o escoamento e a regeneração do látex e determinar a validade desses estudos em plantas jovens, possibilitando a seleção precoce.

Nas áreas amazônicas sempre úmidas, a pesquisa concentra-se agora na enxertia de copa com clones resistentes à doenças, entre os quais destacam-se os clones de *H. pauciflora*. Um melhor conhecimento do comportamento hídrico dos clones de *H. pauciflora*, cuja área de ocorrência natural caracteriza-se por elevada pluviometria durante todo o ano, será importante para melhor compreensão das relações copa x tronco e produtividade de látex.

2.2 Fotossíntese e partição de assimilados

Samsudin & Impens (1978) demonstraram que, em alguns clones de *H. brasiliensis*, as diferenças entre as taxas fotossintéticas estão relacionadas com a resistência à difusão de CO_2 do mesófilo somada à dos sítios de carboxilação. Ceulemans et al. (1984) determinaram as curvas de resposta da fotossíntese líquida à diferentes intensidades de radiação fotossinteticamente ativa em 20 clones de *H. brasiliensis* e 6 outras espécies de *Hevea*, tendo *H. pauciflora* apresentado valores intermediários de ponto de compensação luminosa, rendimento quântico e taxa máxima de fixação de CO_2.

Na Amazônia, tem-se constatado em certos casos proliferação excessiva de microorganismos endógenos na seringueira, conduzindo eventualmente ao definhamento das plantas (Junqueira et al. 1987). Tal fato deverá ser considerado em estudos de fotossíntese, pelas implicações que pode ter na respiração e na estrutura das células.

Informações mais abrangentes são fornecidas pelas análises de crescimento feitas por Templeton (1968, 1969 a,b), em que são demonstradas grandes diferenças entre clones, de *H. brasiliensis* quanto à produtividade primária e à partição de assimilados para produção de borracha, com forte correlação positiva entre produtividade e partição. Entretanto, os clones com maior incremento anual de peso seco corresponderam aos de menor coeficiente de partição. As combinações teóricas favoráveis desses dois índices indicaram a possibilidade de atingir 6 toneladas de borracha seca/hectare/ano.

Na enxertia de copa, é considerada a hipótese de que o coeficiente de partição é uma característica mais associada ao painel e que o uso de copas de alta capacidade fotossintética pode conduzir à obtenção de seringueiras com taxas elevadas de assimilação de matéria seca, associadas a altos coeficiente de partição. Essa é a tarefa principal da pesquisa em andamento no CPAA, que utiliza como ferramentas importantes os parâmetros fisiológicos do látex. É necessário incluir nessas pesquisas, considerando-se o pouco conhecimento sobre nutrição mineral de *H. pauciflora*, o estudo dos efeitos das condições do solo e de nutrição mineral, principalmente sobre o escoamento do látex, com base no efeito negativo dos cations divalentes, em especial o magnésio, sobre a estabilidade do latex (Auzac 1960, Lowe 1962, Collier & Lowe 1969, Woo 1973). *H. brasiliensis* é reconhecidamente uma espécie tolerante à acidez de solo e à toxicidade de alumínio. Por outro, lado o acúmulo de drusas de oxalato de cálcio (metabolicamente inativo), no floema do caule e nas folhas, mesmo em plantas crescendo em solos com baixo teor de cálcio, mostra que *H. brasiliensis* desenvolveu alta capacidade de absorção de cálcio. Falta verificar se as outras espécies de *Hevea* também acumulam drusas de oxalato de cálcio.

Ainda com respeito às copas de *H. pauciflora*, deve-se considerar o maior Índice de Área Foliar e o caráter perenifólio dessa espécie nas condições da Amazônia sempre úmida, além da possibilidade de selecionar clones de maior eficiência fotossintética.

2.3 Fenologia

H. brasiliensis, H. benthamiana e H. microphylla são espécies nitidamente caducifolias. De acordo com Populer (1972), em *H. brasiliensis* a senescência e a abscisão foliar são influenciadas pela ação conjugada do fotoperíodo e do estresse hídrico. Em áreas de maior latitude, em que o período seco corresponde a dias mais curtos, a "hibernação" tende a ser compacta, sendo lenta e gradual em condições opostas.

A fisiologia da senescência e a abscisão foliar em *H. brasiliensis* foram estudadas por Chua (1970). Embora *H. pauciflora* tenha hábito não decíduo, tem-se observado completo desfolhamento em Manaus, em anos com estação seca mais pronunciada, em plantas não adubadas. O estudo comparativo da senescência e da abscisão foliar de *H. pauciflora* e *H. brasiliensis* poderá trazer importantes contribuições, envolvendo também a fisiologia da floração.

3. Laranjeira

3.1. Floração e frutificação

Nas regiões tropicais próximas ao equador, a temperatura e a disponibilidade de água estão dentro da faixa favorável ao crescimento vegetativo vigoroso durante todo o ano, para a maioria das espécies de *Citrus*, desde que satisfeitas as necessidades de nutrição mineral. Falta, entretanto, o período de dormência induzido por temperaturas mais baixas e/ou deficiência hídrica, que provoca a floração abundante e simultânea dos *Citrus* nas regiões sub-tropicais. Desse modo, a floração de laranjeira nos trópicos com chuvas bem distribuídas é gradual, sendo comum a ocorrência simultânea de frutos maduros e verdes e flores em uma mesma planta.

De acordo com Reuther (1975), nas regiões tropicais com período seco bem definido, seria possível controlar a época de floração com irrigação, fazendo coincidir a maturação dos frutos com o período seco do ano seguinte, a fim de melhorar a sua qualidade.

Por outro lado, a demonstração do efeito de aplicação foliar de uréia, via síntese de poliaminas, para induzir floração em plantas com baixo deficit hídrico (Lovatt, 1992), pode abrir margem para o controle de floração sob condições de chuvas bem distribuídas.

4 Coqueiro: relações hídricas

As exigências para crescimento e floração de coqueiro são semelhantes às de dendezeiro, necessitando de ampla disponibilidade hídrica durante todo o ano (Murray 1975). As raízes de coqueiro têm cerca de 4mm de diâmetro, dificultando sua penetração em solos com alto teor de argila. A absorção de água e nutrientes ocorre na faixa logo após a coifa, já que as raízes não dispõem de pêlos absorventes (Murray 1975). A associação com micorrizas reveste-se, assim, de importância e deveria ser melhor estudada.

5 Cupuaçuzeiro

5.1 Tolerância ao sombreamento

O cupuaçuzeiro tem, provavelmente, o mesmo grau de tolerância à sombra do cacaueiro, sendo necessário o sombreamento para o melhor crescimento das plantas jovens. Não foram ainda feitos estudos para definir o melhor manejo de cultura a respeito do sombreamento, sobretudo visando a participação do cupuaçuzeiro em sistema de policultivo. Comparado ao cacaueiro, o cupuaçuzeiro é menos exigente quanto à disponibilidade de nutrientes minerais, acidez do solo e toxicidade de alumínio, o que pode indicar um menor custo de adubação para cultivo de plantas adultas à pleno sol, do que no caso do cacaueiro.

5.2 Relações hídricas

À julgar pelas áreas de ocorrência natural e pelo comportamento em cultivo, é provável que as exigências hídricas do cupuaçuzeiro também sejam semelhantes às do cacaueiro. Perdas importantes de frutos podem ocorrer quando, imediatamente após períodos de stresse hídrico, ocorrem chuvas pesadas, causado rachaduras na casca dos frutos, após a rehidratação. Há menor produção de frutos nos anos com estação seca mais pronunciada.

6 Pupunheira: relações hídricas

A queda de frutos jovens associada à curtos períodos secos durante a estação normalmente chuvosa, é uma indicação de que a produção de frutos é afetada por estresses hídricos pouco severos. É assim provável que as observações feitas para o coqueiro sejam também válidas para a pupunheira.

7. Urucuzeiro

Trata-se de espécie rústica, que cresce e produz razoavelmente sob as condições de manejo dos pequenos agricultores, sem aplicação de fertilizantes. O acúmulo de carotenoides nas sementes leva à conjecturar quanto ao papel de um provável nível também alto de carotenoides nas folhas, proporcionando maior proteção contra fotooxidação sob alta intensidade luminosa (Demmig et al. 1988, 1992), sendo talvez interessante um estudo comparativo entre o urucuzeiro e outras espécies.

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Condução do tronco e enxertia de copa da seringueira

Vicente H. de F. Moraes

Zusammenfassung:

Wuchslenkung des Stammes und Kronenaustausch beim Kautschukbaum

In der Kulturführung von Hevea sp. ist es üblich, die Seitentriebe der Sproßachse bis zum Erreichen einer Höhe von 2,10 m auszugeizen. Bei den auf der SHIFT-Versuchsfläche verwendeten Pflanzen war das Ausgeizen weniger oft erforderlich als aus der Literatur bekannt. Dieser Umstand dürfte auf die charakteristischen Eigenschaften des eingesetzten Klones Fx 4098 zurückzuführen sein. Die Okulierung der Krone des Kautschukbaumes erfolgt im allgemeinen , wenn 70% der Pflanzen eine Höhe von 1,90m erreicht haben. Obwohl die Kautschukpflanzen zehn Monate nach Pflanzung mindestens zwei Austriebe durchlaufen haben, wurde dieser Prozentsatz im Durchschnitt noch nicht erreicht. Allerdings waren Pflanzen, die in der Baumschule mit Mykorrhizapilzen inokuliert wurden, stets größer als nicht-inokulierte Kontrollpflanzen, unabhängig davon, welchem Düngungsregime sie unterzogen wurden. Besonders deutlich ist der Unterschied zwischen den Kautschukpflanzen der Monokultur, die ausnahmslos nicht inokuliert sind, und denen des Mischkultursystems III, bei denen Mykorrhizapilze eingesetzt wurden. Die inokulierten Pflanzen können demnach eher okuliert werden als die Kontrollpflanzen. Darüber hinaus ergaben sich signifikante Unterschiede zwischen den Pflanzen der verschiedenen Blöcke. Von Block A nach Block E nahm die durchschnittliche Höhe der Kautschukpflanzen ab. Dies deutet auf eine Heterogenität der Fläche, möglicherweise Unterschiede in physikalischen oder chemischen Eigenschaften des Bodens, hin. Die Anzahl der Pflanzen, die aufgrund ihres unzureichenden Wachstums ersetzt werden mußten, nahm von Block A nach Block E zu. Bei Entnahme der Pflanzen war festzustellen, daß das Wurzelsystem schlecht entwickelt war. Seitenwurzeln waren auschließlich an der Spitze der Pfahlwurzel und in nur geringer Anzahl ausgebildet. Auf die Bodenoberfläche applizierter Dünger kann aus diesem Grund nicht von der Pflanze aufgenommen werden, was Kümmerwuchs zur Folge hat. Die Unterschiede zwischen den Pflanzen der verschiedenen Blöcke in bezug auf ihre Vitalität wurden auch bei der Okulierung deutlich. Von Block A nach Block E nahm die Anzahl der Pflanzen, die okuliert werden konnten, aufgrund der abnehmenden Höhe ebenfalls ab. Zudem verlief die Okulierung in den Blöcken D und E nur zu etwa 55% erfolgreich, während diese Rate in den Blöcken A bis C bei über 90% lag.

1 Condução do tronco

Consiste em rondas periódicas para remoção das brotações de gemas ao longo do tronco até a altura de 2,10m, onde aproximadamente é feita a enxertia de copa.

A partir de maio de 1993 não houve mais necessidade de desbrotas, tendo-se consumido um total de 4 jornadas de trabalho (32,5 horas). Nos manuais de heveicultura, a previsão é de 5 jornadas por ha (476 plantas) para desbrota, o que demonstra ter havido sensível redução do consumo de mão-de-obra, considerando-se o total teórico de 1.100 seringueiras do experimento. Tal fato pode ser atribuído às características favoráveis do clone Fx 4098, quanto à dominância apical e à dormência das gêmas, ao longo do caule das plantas jovens.

2 Atingimento da altura mínima para a enxertia de copa

A enxertia de copa deve ser iniciada quando cerca de 70% das plantas já tem altura suficiente para que possa ser feita entre 1,90 a 2,10m de altura, tendo as plantas altura total geralmente superior a 2,30m.

Em novembro de 1993, decorridos 10 meses após o plantio das mudas, já com 2 ou mais lançamentos, essa condição não foi atingida e evidenciou-se grande desuniformidade de crescimento. Foi então medida a altura de todas as plantas, cujos dados são apresentados na Tabela 1, onde verifica-se que, em cada par de tratamentos com e sem inoculação de fungo micorrízico, as médias dos tratamentos com micorriza são invariavelmente mais altas.

A análise da variância mostrou que houve diferenças significativas a 1% entre tratamentos e entre blocos. A classificação dos tratamentos pelo teste de Student-Newman-Keuls, de comparações múltiplas (Tabela 2), revelou diferenças significativas apenas entre o tratamento sistema 6 (monocultivo) e os tratamentos S3/30C e S3/100C, respectivamente com 30 e 100 % da adubação recomendada usualmente, ambos com inoculação de fungo micorrízico[1].

A Tabela 3 refere-se à análise apenas dos tratamentos do Sistema 1 e nesse caso evidencia-se a superioridade dos tratamentos S1 30C (30% da dose de adubos) com

[1] C = com fungo micorrízico, S = sem fungo micorrízico; S = sistema; pela vista geral do experimento ver *Lieberei et al.*

inoculação de micorriza e S/100C (100% da dose de adubos) com micorriza, sobre os outros dois tratamentos correspondentes, sem inoculação. A Tabela 4 apresenta os resultados da análise apenas do Sistema 3, em que, paradoxalmente, não houve diferenças significativas. Tal fato pode ser conciliado em relação ao Sistema 1, se considerada a possibilidade de ocorrência de erro experimental na instalação ou condução dos tratamentos, tendo em vista os argumentos a seguir:

Houve diferenças significativas entre blocos (Tabela 5) indicando haver diferença de condições do solo. Entretanto, nos experimentos com seringueira, em que o plantio é feito em covas grandes reenchidas com solo orgânico superficial, o efeito das diferenças localizadas de fertilidade do solo é atenuado no primeiro ano após o plantio, sobretudo quando são aplicadas doses corretas de fósforo e de micronutrientes (zinco e cobre, principalmente). Entre tratamentos, deveriam ser esperadas respostas significativamente diferentes apenas para doses de adubo e presença ou ausência de inóculo de fungo micorrízico no primeiro ano após o plantio, uma vez que nesse período o tamanho das plantas ainda não deve provocar interações ou efeitos aditivos entre as espécies componentes dos sistemas. Por outro lado, as diferenças altamente significativas entre blocos mostram a necessidade de melhor caracterização do solo das parcelas, incluindo parâmetros de física do solo.

Na Tabela 6 é apresentado por bloco o número de plantas com debilidade progressiva, evidenciada pela forte redução do comprimento dos entrenós sucessivos e do tamanho das folhas (plantas raquíticas). Essas plantas perdem prematuramente as folhas dos lançamentos anteriores e o tamanho dos novos lançamentos indica que estes são formados às custas das reservas em exaustão, ou seja, tais plantas tendem a morrer de inanição.

O exame das raízes dessas plantas, após o arranquio para substituição, mostrou que a pivotante estava retorcida ou tinha um desvio na horizontal, provavelmente correspondendo à resistência do fundo do saco de plástico, e que havia um número reduzido de raízes laterais apenas nas extremidades das pivotantes. O maior número de plantas raquíticas foi encontrado no bloco D, seguido de E e C (Tabela 6). Tais plantas, foram substituidas nos blocos C, D e E, em janeiro de 1994, por tocos altos do clone Fx 4098, obtidos do mesmo viveiro de porta-enxertos onde foram produzidos os tocos de raiz nua e gemas dormentes plantadas originalmente em viveiro de sacos de plástico, para obtenção das mudas com 2 lançamentos usados no experimento. A Tabela 6 mostra também a frequência de falha de plantio (plantas mortas), após o replantio para preenchimento das falhas originais e de plantas menos vigorosas porém ainda consideradas recuperáveis, a julgar pelo comprimento dos últimos lançamentos. Nessas plantas, a aplicação das doses previstas de adubo fosfatado foi feita nos blocos C, D e

E, em furos de cada lado das plantas até à profundidade próxima das raízes laterais formadas apenas nas pontas das pivotantes. A Tabela 6 mostra o número dessas plantas por bloco, bem como a altura média das plantas. O registro de campo, entretanto foi feito por parcelas por blocos. A frequência de falhas, 5% para o total do experimento, está abaixo do limite admissível em heveicultura e não necessita de novas intervenções.

A formação de mudas com o plantio de tocos de raiz nua e gemas dormentes é comumente adotada no Brasil e em outros países onde se cultiva a seringueira. No preparo do toco de raiz nua são geralmente perdidas as raízes laterais ainda finas, e a indução da rizogênese com o ácido alfa-naftaleno acético acentua a tendência de formação inicial de raízes fortemente geotrópicas apenas nas extremidades das pivotantes. Se as covas não forem suficientemente profundas, essas raízes laterais iniciais não exploram o solo orgânico adubado da cova por estarem situadas no subsolo, de muito baixa fertilidade. Em solos como o de Manaus, com teor de argila ao redor de 80%, essas raízes laterais também não têm acesso ao fósforo aplicado no solo superficial, nas adubações subsequentes ao plantio. Em tais casos tem-se conseguido a retomada de crescimento satisfatório após a aplicação do fósforo em furos de trado até a profundidade em que se encontram as raízes. Com o aumento da capacidade fotossintética pelo aumento da área foliar, a disponibilidade de substrato orgânico permite então a emissão de novas raízes mais próximas da superfície do solo, com o que são obtidas respostas às aplicações superficiais de fósforo nos anos subsequentes.

A perda das raízes laterias originais do toco de raiz nua sugere, também, que melhor efeito da inoculação com fungo micorrízico deve ser obtido com o preparo das mudas a partir do semeio das sementes pré-germinadas diretamente nos sacos de plástico ou em covas no próprio local de plantio definitivo, quando se trata de áreas pequenas sem impedimentos de locomoção, como tocos ou troncos, que dificultam os tratos culturais dos porta-enxertos muito distanciados entre si.

3 Enxertia de copa

Tendo em vista a desuniformidade de crescimento e a dificuldade crescente, com a altura das plantas, para a aplicação de fungicida, a enxertia de copa foi iniciada em novembro de 1993, com menos de 70% das plantas aptas à enxertia. O clone de copa do experimento é o PA 31, do qual se dispõe de maior número de informações. A Tabela 7 contém os dados sobre o número de enxertos feitos, número de enxertos bem sucedidos (pegos) e percentagem de plantas enxertadas por bloco, inclusive com os dados da segunda ronda, feita em janeiro de 1994 e, cujo pegamento ainda não foi verificado.

Observa-se (Tabela 7) que os dois melhores blocos (A e B), deverão ter a enxertia de copa completada com mais uma ronda, o que é um bom índice, considerando-se o sucesso muito bom da enxertia. Entretanto na primeira ronda, principalmente no bloco D, o número de plantas enxertadas foi muito baixo, sendo também baixo nos blocos C e E. Houve pegamento de apenas cerca de metade dos enxertos nos blocos D e E, em consequência do pouco vigor, mesmo das plantas mais altas.

Na primeira ronda, o rendimento foi de 72 enxertos por homem/dia, o qual seria mais elevado com maior percentagem de plantas enxertáveis (90 enxertos por homem/dia).

Tabela 1:
Altura das seringueiras [m]: Médias dos 5 blocos por tratamentos. Novembro de 1993.

Trata-mentos	S1 30S	S1 30C	S1 100S	S1 100C	S3 30S	S3 30C	S3 100S	S3 100C	S4 -	S6 -
Altura	1,78	1,94	1,81	2,05	1,92	2,14	1,86	2,12	1,84	1,75

30 = 30% da dose usual de adubação
100 = 100% da dose usual de adubação
S = Sem inoculação de fungo micorrízico
C = Com inoculação de fungo micorrìzico

Tabela 2:
Altura das seringueiras [m]: Classificação dos tratamentos pelo teste de comparações multiplas, envolvendo todos os tratamentos. Contrastes significativos a 1%.

S3 30C	S3 100C	S1 100C	S1 30C	S3 30S	S3 100S	S4 -	S1 100S	S1 30S	S6 -
2,14a	2,12a	2,05ab	1,94ab	1,92ab	1,86ab	1,84ab	1,81ab	1,78ab	1,75b

OBS:
Valores seguidos pelas mesmas letras não diferem significativamente a 1 % pelo teste de Student-Newman-Keuls.

Tabela 3:
Altura das seringueiras [m]: Classificação dos tratamentos do Sistema 1, Contrastes significativos a 1%.

S1 100C	S1 30C	S1 100S	S1 30S
2,05a	1,94a	1,81b	1,78b

Tabela 4:
Altura das seringueiras [m]: Classificação dos tratamentos do Sistema 3. Contrastes não significativos.

S3 30C	S3 100C	S3 30S	S3 100S
2,14a	2,12a	1,91a	1,86a

Tabela 5:
Altura das seringueiras [m]: Classificação dos blocos. Contrastes significativos a 1%

Bloco A	a	Bloco B	a	Bloco C	b	Bloco E	bc	Bloco D	bc

OBS:
Valores seguidos pelas mesmas letras não diferem significativamente a 1 % pelo teste de Student-Newman-Keuls.

Tabela 6:
Altura média [m] das seringueira: N° de falhas (plantas mortas), plantas raquíticas e plantas fracas recuperáveis por bloco.

Bloco	Altura média [m]	N° de falhas	N° de plantas raquiticas	N° de fracas recuperáveis
A	2,20	2	3	6
B	2,06	3	6	5
C	1,80	3	16*	8**
D	1,61	1	44*	48**
E	1,67	2	25*	22**

* Substituídas por toco alto
** Aplicação de superfosfato triplo em furos

Tabela 7:
Enxertia de copa. N° de enxertos feitos, n° de enxertos pegos e % de plantas enxertadas em relação ao total, na 1ª e na 2ª ronda de enxertia, por blocos.

	1ª Ronda			2ª Ronda	
Blocos	Enxertos feitos	% plantas enxertadas	Enxertos pegos	Enxertos feitos	% acumulada de plantas enxertadas
A	103	47,9	101	71	80,9
B	107	50,7	106	59	78,7
C	66	30,5	62	53	54,8
D	32	14,6	18	35	30,6
E	60	27,5	31	42	46,8
Totais	368	-	318	268	-

Avaliação de espécies florestais estabelecidas em consórcio com aplicações de fungo micorrízicos, e adubação

Edinelson J. M. Neves e Gilvan C. Martins

Zusammenfassung:

Bewertung der mykorrhizierten und gedüngten Baumarten in Mischkultur
Höhe und Stammdurchmesser der agroforstlich nutzbaren Pflanzenarten des Experiments werden sechs Monate nach der Anpflanzung gemessen und die Unterschiede statistisch ausgewertet. Bei dem Vergleich ergibt sich, daß keine statistisch absicherbaren Unterschiede zwischen den Pflanzen der verschiedenen Behandlungen nachweisbar sind, jedoch treten Unterschiede zwischen den Blöcken auf, wobei die Pflanzen des Blocks a die höchsten Mittelwerte aufweisen. Paricá ist die Baumart, die das beste Höhenwachstum zeigt.

1 Introdução

Com uma área de aproximadamente 280 milhões de hectares de floresta tropical densa, representando 56% do espaço geográfico da Amazônia legal, e um potencial madeireiro estimado em 50 milhões de metros cúbicos, a Amazônia é, atualmente, palco de um processo intensivo de ocupação humana.

Essa região caracteriza-se por apresentar solos intemperizados, de elevada acidez e baixa disponibilidade de nutrientes. Apesar desso, mais de 40 milhões de hectares de floresta, na Amazônia legal, já foram desmatados para diferentes fins, existindo, com isso, a necessidade de desenvolver técnicas de manejo e recuperação que restaurem o potencial produtivo dessas áreas.

O plantio de espécies florestais que produzam frutos, óleo e madeira em sistemas de policultivos são alternativas viáveis para recuperar as referidas áreas, diminuindo, com isso, a pressão sobre as florestas naturais.

O presente relatório analisa o comportamento silvicultural de diferentes espécies florestais, aos seis e doze meses de idade, submetidas a diferentes tratamentos.

2 Metodologia

O experimento foi instalado no Campo Experimental do Centro de Pesquisa Agroflorestal da Amazônia Ocidental (CPAA), localizado no km 25 da rodovia AM 010 que liga Manaus a Itacoatiara, Estado do Amazonas. A área, anteriormente cultivada com seringueira, encontrava-se abandonada. Foram plantadas as seguintes espécies florestais: castanha-do-Brasil (*Bertholletia excelsa*) ; mogno (*Swietenia macrophylla*) ; paricá (*Schizolobium amazonicum*); andiroba (*Carapa guianensis*) e seringueira (*Hevea brasiliensis*), como componentes dos seguintes sistemas:

Sistema 2: urucum ; castanha-do-Brasil ; cupuaçu e pupunha
Sistema 3: paricá ; serigueira ; cocos ; cupuaçu e citrus
Sistema 4: seringueira ; andiroba ; mogno e paricá

Nas entrelinhas do sistema 2, foi plantado mandioca, e nas do sistema 3, mandioca, milho e feijão caupi. Os sistemas 2 e 3 receberam os seguintes tratamentos: a) 30% da adubação recomendada; e b) 100% da adubação recomendada, ambos com todas as plantas inoculadas com o fungo micorrízico *Glomus etunicatum*; c) 30% da adubação recomendada e d) 100% da adubação recomendada, ambos sem inoculação com *Glomus etunicatum*. O sistema 4 recebeu apenas 30% da adubação recomendada, com todas as plantas inoculadas com o fungo micorrízico. Os sistemas 2 e 3, constituem-se de quatro tratamentos e o sistema 4 de apenas um tratamento, todos distribuídos em blocos ao acaso com 5 repetições. A área de cada parcela é de 32m X 48m. No sistema 2 foram plantadas 12 árvores de castanha espaçadas de 12.80m X 8,00m, enquanto que no sistema 3 foram plantadas 5 árvores de paricá com 16m X 23m de espaçamento.No sistema 4 existem 12 árvores de seringueira, 4 de andiroba, 4 de mogno e 4 de paricá, espaçadas por 8m X 20m, 12m X 20m, 12m X 20m e 12m X 20m respectivamente. A adubação recomendada foi de 30g de N na forma de uréia/planta ; 50g de P_2O_5 na forma de superfosfato triplo/planta e 40g de K_2O na forma de cloreto de potássio/planta. O plantio foi realizado em fevereiro/93.As plantas, nos diferentes sistemas, estão sendo avaliadas a cada 6 meses no primeiro ano e anualmente a partir desta idade em relação ao indice de sobrevivência (%), altura (m) e diâmetro do caule à altura do peito (cm).

Foi feita analíse de variância e, para a comparação de médias foi utilizado o teste de Tuckey, à nível de 5% de probabilidade.

3 Resultados parciais

Quando da realização da análise de variância, a mesma demonstrou não haver diferença significativa entre os tratamentos para a variável altura no sistema 2, altura e diâmetro à altura do peito no sistema 3. No sistema 4, considerando-se as espécies como tratamento, pela diferenca entre médias apresentada, observou-se que paricá é a espécie com melhor comportamento, tanto em altura com diâmetro. A mesma análise revelou haver diferença significativa entre blocos, sendo que o bloco A é o que apresenta maiores média.

Tabela 1:
Dados de altura (H) e diâmetro à altura do peito (DAP) aos 6 e 12 meses de idade.

			6 meses		12 meses	
Especie	Sistema	Bloco	H (m)	DAP (cm)	H (m)	DAP (cm)
Castanha	2	A	0,89	-	1,45	1,27
		B	0,79	-	1,17	-
		C	0,74	-	1,04	-
		D	0,75	-	1,03	-
		E	0,75	-	0,95	-
altura média referente a 48 plantas por bloco						
Paricá	3	A	3,26	4,4	5,91	8,75
		B	2,88	3,8	5,84	8,36
		C	3,10	3,9	6,72	8,97
		D	2,96	3,8	6,83	8,89
		E	2,30	2,9	4,35	5,64

continuação:						
altura e diâmetro médio referente a 20 plantas por bloco						
seringueira	4	A	2,05	1,5	2,20	1,87
		B	1,38	-	1,93	1,44
		C	1,66	1,1	2,10	1,52
		D	1,49	1,3	1,80	1,49
		E	1,45	1,2	1,66	1,56
altura e diâmetro médio referente a 12 plantas por bloco						
paricá	4	A	2,65	3,1	4,57	5,70
		B	2,00	2,8	4,18	11,03
		C	1,90	2,5	2,73	3,32
		D	2,43	3,0	4,33	6,10
		E	1,96	2,5	3,6	4,54
altura e diâmetro médio referente a 4 plantas por bloco						
mogno	4	A	1,60	1,45	2,48	3,30
		B	0,65	-	1,45	1,90
		C	1,08	-	2,12	1,78
		D	1,20	-	2,12	2,47
		E	1,42	1,30	2,47	2,98
altura e diametro médio referentes a 4 plantas por bloco						
andiroba	4	A	0,78	-	1,53	2,23
		B	0,55	-	0,78	-
		C	0,80	-	1,43	1,70
		D	0,55	-	1,05	-
		E	0,72	-	1,15	-
altura média referente a 4 plantas por bloco						

H = altura
DAP = diâmetro à altura do peito

Escolha das espécies

Acilino do Carmo Canto

Zusammenfassung:

Artenauswahl

Der wichtigste Faktor, der über den Erfolg eines agro-forstlichen Systems (der feuchten Tropen) entscheidet, ist die schwierige Auswahl von Pflanzenarten mit ökonomischem Wert, die dazu in der Region und auf den zur Verfügung stehenden Standorten erfolgreich angepflanzt werden können. Nachfolgend werden verschiedene Gesichtspunkte für eine Auswahl erläutert und anschließend Eigenschaften der in der Mischkulturplantage eingesetzten ausdauernden Kulturpflanzen Kautschuk, Cupuaçu, Pupunha, Zitrus, Urucu, Kokos, Paranuß, Mahagoni, Andiroba und Paricá genannt, welche mit dem ökonomischen Wert und der Vermarktbarkeit der Pflanzenprodukte eng verknüpft sind. Der Aufsatz wird durch eine kurze Literaturauswahl ergänzt.

1 Aspectos econômicos e ecológicos da escolha

O fator mais importante que decide o sucesso de um sistema agroflorestal é a escolha das espécies de plantas de valor econômico, que podem ser cultivadas na mesma área. O ponto importante aqui, é determinar a adaptabilidade das espécies a serem incluídas nos sistemas agroflorestais, independentemente se são convencionalmente agrícolas, florestais ou de outro grupo de plantas.

Assim, dentro de uma determinada faixa climatológica de adaptação de um espécie a uma localidade, as principais considerações para determinar a sua adequação a sistemas agroflorestais, são: adaptação à sombra, habilidade para produzir razoavelmente em condições sub-ótimas de nutrientes, água e luz, e hábitos especiais de crescimento (se houver) que necessitam para serem cultivadas conjuntamente com outras espécies.

Além da adaptabilidade aos aspectos edafoclimáticos (fundamento agroecológico), as culturas selecionadas para compor os sistemas de consórcio devem apresentar características de mercado atual e potencial bastante distintos entre si (fundamento sócio-econômico dos sistemas). Para uma tomada de decisão à respeito da implantação de culturas perenes, é de suma importância a avaliação do mercado consumidor atual mas, principalmente, de suas potencialidades de ampliação ou de saturação.

Sem pretender fazer uma análise de mercado das culturas envolvidas nos consórcios, são levantados alguns aspectos básicos que foram considerados na tomada de decisão das culturas à plantar e da quantidade de cada uma delas.

Em primeiro lugar, considerou-se que as culturas perenes do tipo arbóreo (agrícolas e florestais), e mesmo arbustivo, têm um ciclo de vida produtivo bastante longo, o que permite um risco menor a médio prazo, uma vez que sua exploração pode ser ajustada às condições do mercado. As culturas semiperenes, como mamão e urucu, devem ser analisadas com mais cuidado, uma vez que sua adequação à possíveis flutuações de mercado deve ser imediata e seu cultivo pode coincidir com ciclo de queda de preços.

As culturas alimentares (milho, feijão e mandioca), devem ser utilizadas no período inicial de exploração, porque estas são a base de sustentação das pequenas propriedades e para aproveitar os espaços entre as culturas perenes que ficam descobertas[1].

O uso de espécies florestais nos sistemas agroflorestais, com a finalidade de produzir alimentos e produtos florestais com melhor utilização do solo, tem sido recomendado, pois o valor monetário agregado pela venda da madeira e outros produtos, poderá aumentar o valor bruto de produção/ha/ano, bem como a receita líquida das atividades agrícolas/ha/ano, gerando para o produtor rendas adicionais, proporcionais ao número de hectares trabalhados.

2 Características econômicas das espécies plantadas

2.1 Seringueira (*Hevea brasiliensis* M.Arg.)

Apesar de todos os problemas para viabilizar o plantio racional devido, principalmente, às doenças, a seringueira apresenta um mercado interno altamente promissor, quando se considera o potencial que tem na substituição das importações e mesmo de ampliação do mercado interno. Além disso, os seringais cultivados apresentam um custo de produção de borracha potencialmente inferior ao observado em áreas de extrativismo, o que os coloca em condições privilegiadas em relação à principal parcela de produção de borracha natural do país.

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[1] ver tambem, *Preisinger, Siqueira & Coelho*

Trata-se de uma planta perene ajustada aos solos pobres e ácidos da Amazônia. A maior preocupação do produtor deve ser no sentido de obter a melhor eficiência agronômica do cultivo para, através dela, buscar rentabilidade econômica, uma vez que cultivos mal implantados ou tecnologicamente deficientes, em qualquer situação, tendem a ser alijados do processo produtivo.

2.2 Cupuaçu (*Theobroma grandiflorum* Schum.)

O mercado para o cupuaçu é basicamente regional, tendo pouca significância, ainda, para o mercado national e mesmo internacional. O fruto do cupuaçuzeiro é, no entanto, citado como um dos que possui condições para conquistar e ampliar o mercado consumidor, em forma de suco e de polpa.

Os preços elevados que o fruto e a polpa congelada de cupuaçu atingiram nos últimos anos, no mercado de Manaus, levam a crer que ocorreu um incremento no consumo, sem que antes houvesse qualquer estímulo ao plantio da cultura, talvez por falta de tecnologia. A manutenção de preços estimulantes se consolidará na medida em que a conquista de mercado consumidor for constantemente buscada.

O aproveitamento da semente de cupuaçu para a produção de chocolate branco (cupulate) depende do mercado de chocolate, que está passando por um período não favorável. A vantagem que o uso da semente de cupuaçu pode apresentar em relação ao cacau, é que a semente do primeiro é considerada, atualmente, um subproduto sem qualquer uso e valor comercial.

Fruteira tipicamente amazônica, encontrada em estado silvestre no sub-bosque da floresta, é uma espécie que adapta-se bem em consórcio com outras espécies perenes.

2.3 Pupunha (*Bactris gasipaes* H.B.K.)

A pupunheira é uma palmeira do trópico americano, sendo bastante comum nos quintais e pomares de pequenos produtores da região. É explorada quase exclusivamente para a produção de fruto e recentemente existem algumas plantações para produção de palmito, principalmente na Costa Rica e Peru. O consumo do fruto da pupunheira é muito restrito, o que limita sua produção para o consumo in natura, diante do atual mercado. O período de safra, bastante reduzido, também concorre para limitação do mercado, que só poderá ser ampliado através da industrialização.

Assim, o estímulo ao cultivo da pupunheira, em escala maior, só poderá ser implementado mediante um planejamento calcado na industrialização dos excedentes que podem ser obtidos no período de safra, ou seja, retirar do mercado aquilo que pode vir a afetar o preço de forma a desestimular sua exploração por parte do produtor.

Por ser palmeira de perfilhação abundante e produzir palmito de ótima qualidade, há perspectivas de estímulo de produção para esse fim, além da utilização dos resíduos da indústria para alimentação animal e humana.

2.4 Citros (*Citrus* spp.)

O mercado de citros do Estado do Amazonas, em especial nos municípios que podem abastecer mais facilmente a região metropolitana de Manaus (Rio Preto da Eva e Presidente Figueiredo), é bastante promissor.

Dentre os citros destaca-se a laranja, que é a que possui mercado mais amplo e maior demanda potencial. O mercado consumidor de Manaus de frutos in natura é tradicionalmente abastecido pelo Sudeste do país (São Paulo). Recentemente, a produção regional passou a fazer parte do mercado local de forma mais significativa. As vantagens advindas do custo de transporte e a qualidade dos frutos não expostos aos desgastes causados pelas longas distâncias percorridas, tendem a formar um panorama favorável ao cultivo local de citros.

A principal preocupação do produtor deve ser com o aspecto tecnológico, que deve ser competitivo em um mercado que hoje é bastante favorável, mas que no futuro poderá atingir níveis de saturação que redundem em queda real de preço. Devem ser cultivadas variedades com períodos de maturação distintos, para absorver melhor as vantagens de produção em período de menor oferta.

2.5 Urucu (*Bixa orelana* L.)

É um dos exemplos mais recentes de cultura estimulada na região, com base em informações de mercado potencial, que não se concretizaram até o momento.

A sua importância econômica reside, principalmente, no teor de suas substâncias corantes, cujo uso tem sido aumentado, não somente pela proibição da utilização de corantes sintéticos, como por a sua utilização nas indústrias de alimentos e cosméticos. Além desses aspectos, os altos teores de alfa e beta caroteno (provitamina A) do urucu, conferem-lhe importantíssimo papel para o homem, em face da carência dessa vitamina na população mundial em todas as camadas sociais.

A cultura do urucu deve consolidar-se, não como uma cultura de primeira grandeza, porém como mais uma alternativa para a diversificação de cultivos na propriedade agrícola. Sua expansão dependerá da conjuntura do mercado mundial em termos de corantes competitivos de essências aromáticas. Outros fatores que poderão induzir a sua expansão são: a qualidade do produto a ser obtido (altos teores de princípio corante) e o processamento industrial.

2.6 Coco (*Cocus nucifera* L.)

O coqueiro é uma palmácea muito cultivada em quintais em toda a Amazônia. Atualmente existem alguns plantios para produção de coco para consumo "in natura" (como água-de-coco).

É uma planta que, por apresentar uma copa que permite uma passagem considerável de luz, presta-se muito bem para ser utilizada em consórcios e sistemas agroflorestais. Além disso, seu sistema radicular, não sendo muito profuso, permite que outras espécies possam ser plantadas em sua proximidade.

2.7 Castanha-do-Brasil (*Bertholletia excelsa* H.B.K.)

À prevalecer o processo desordenado de expansão da fronteira agrícola na Amazônia, somente o plantio de castanheira poderá repor, a longo prazo, a produção dessa importante fonte de proteína.

Por se tratar de um produto extrativo a longo prazo, os níveis de preços tendem a crescer devido à redução da oferta, chegando a um ponto em que o extrativismo será substituído pelo cultivo racional. Entretanto, o desenvolvimento de plantios comerciais fica na dependência do aprimoramento tecnológico para superar as limitações ainda existentes. A expansão do plantio de castanha-do-Brasil tem importância na reposição de áreas perdidas pela expansão da fronteira agrícola e como possibilidade para produção de frutos (até 500 hl/ha) e madeira (150 a 170m^3/ha de madeira comercial entre 30-40 anos).

2.8 Mogno (*Swietenia macrophylla* King.)

O mogno é uma das espécies mundialmente mais importantes no mercado madeireiro, e sua madeira alcança preços elevados, sendo a mais cara da Amazônia. Por ser uma espécie intensivamente explorada, já está entre as que se encontram em risco de extinção.

Sua silvicultura tem sido estudada há bastante tempo, não só no Brasil como também em outros países, e o maior problema encontrado com o cultivo do mogno, à pleno sol, é o ataque do lepidóptero dos ponteiros (*Hypsipyla grandella*), que prejudica sobremaneira as plantas. O controle químico dessa praga é impraticável. Uma das soluções que está sendo proposta é o plantio da espécie em sistemas agroflorestais ou em linhas de enriquecimento de capoeiras, que minimizam a incidência da praga.

2.9 Andiroba (*Carapa guianensis* Aubl.)

Espécie ocorrendo em toda região amazônica, possui madeira moderadamente pesada (densidade 0,73g/cm); dura, porém fácil de fender; pouco resistente às intempéries, mas inatacável por insetos.

A madeira é muito usada em construção naval e civil, em carpintaria, mobiliária para confecção de portas e caixotaria. Produz anualmente grande quantidade de sementes, que encerram 70% de óleo insetífugo e medicinal.

A árvore apresenta bom desenvolvimento e é indicada para plantios em áreas degradadas na região amazônica.

2.10 Paricá (*Schizolobium amazonicum* Ducke)

O paricá, sendo uma espécie de madeira branca, muito leve e maciça, normalmente é indicado para miolo de painéis e portas, saltos para calçados, compensados, caixotaria leve e pesada.

É uma espécie de crescimento rápido, alcançando facilmente 8-10m aos 2 anos. É ereta, produzindo copa não muito densa, e é considerada ótima para reflorestamento de áreas degradadas de preservação permanente, em composições mistas e agrosilvicultura.

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Avaliação de Custos de Produção em Sistemas de Policultivos

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Zusammenfassung:

Analyse der Produktionskosten in Mischkultursystemen

Es wurden die Kosten verglichen, die die im Test befindlichen Anbausysteme und ihre Varianten (Düngung, Einsatz von Mykorrhizapilz-Inokulum) verursachen. Dabei wurden sowohl die Kosten für die Anlage der Systeme als auch die für das Management berücksichtigt. Die Investitions-/Materialkosten und die Kosten für Arbeitskräfte sind getrennt aufgeführt. Die Analyse ergibt u.a., daß die Systeme 1, 2 und 3 sich hinsichtlich Arbeitsintensivität kaum voneinander unterscheiden und daß der Einsatz von Mykorrhizapilz-Inokulum die Kosten nur wenig erhöht. Dagegen fallen bei System 1 die Materialkosten ins Gewicht, verursacht durch die notwendigen Düngergaben für Papaya. Die Monokultursysteme verursachen niedrigere Kosten als die Mischkultursysteme, abgesehen von der Pupunha-Monokultur, die die teuerste unter den Monokulturen ist. Da die zu erwartenden Einnahmen bisher nicht errechnet werden konnten und wichtige sozio-ökonomische Daten fehlen, sind Abschätzungen der Rentabilität derzeit nicht möglich.

1 Introdução

A utilização inadequada de monocultivos, na região, gerou um alto número de áreas abandonadas, por essa razão, existe a necessidade da recuperação dessas áreas através de sistemas de policultivo, tentando estabelecer condições semelhantes às existentes na floresta primária.

Com esse objetivo, o projeto SHIFT busca desenvolver um sistema de produção agrícola, através de policultivos adaptados à região tropical úmida da Amazônia, que seja social e economicamente viável.

2 Metodologia

Foi realizado um levantamento de custos nos diferentes sistemas testados.

Sistema 1	seringueira (24), pupunha (64), cupuaçu (10), mamão (128).
Sistema 2	castanha (12), pupunha (32), urucum (24), cupuaçu (15) e mandioca.
Sistema 3	seringueira (16), laranja (10), coqueiro (8), cupuaçu (5), paricá (5) e mandioca, milho e feijão.
Sistema 4	seringueira (12), paricá (12), andiroba (4) e mogno (4).
Sistema 5	Vegetação natural
Sistema 6	Monocultivo de seringueira (48).
Sistema 7	Monocultivo de cupuaçu (30).
Sistema 8	Monocultivo de pupunha (384).
Sistema 9	Monocultivo de laranja (30).

Nos sitemas 1, 2 e 3 estão sendo testados dois níveis de adubação, combinados com uso de fungo micorrízico, resultando em quatro tratamentos:

- 100% de adubação com fungo micorrízico.
- 100% de adubação sem fungo micorrízico.
- 30% de adubação com fungo micorrízico.
- 30% de adubação sem fungo micorrízico.

Os dados utilizados para o estudo foram coletados diariamente no período de agosto/92 à dezembro/93.

As atividades de mão-de-obra foram mensuradas em tempo de horas gasto por atividade e por parcela (48 x 32 m) para cada sistema, onde 8 horas de trabalho equivale a uma diária, com o custo de U$ 6.0.

Os insumos foram adquiridos no comércio local e os preços transformados em dólar. O valor das mudas micorrizadas foi determinado através do acréscimo de 5% do valor da muda não micorrizada. O custo da aplicação do fungo micorrízico no plantio das culturas anuais, foi acréscido de uma diária em relação ao plantio das parcelas sem fungo micorrízico.

Os dados coletados no campo foram separados por atividades de cada sistema, dentro de cada tratamento. Nas atividades estão incluídos dados de preparo de área, plantio, adubação (plantio e manutenção), capinas e coroamento das plantas.

Os custos de tratos fitossanitários aplicados nos sistemas não foram considerados neste relatório.

3 Resultados

Na Tabela 1, encontram-se os fatores de custos gerais de mão-de-obra e insumos utilizados em uma parcela de cada tratamento dos sistemas testados.

Observa-se que os sistemas 1,2 e 3 não apresentaram variação de custos de mão-de-obra para culturas perenes em todos os tratamentos, havendo apenas, uma pequena diferença de custo total entre os tratamentos, demonstrando que a presença de fungo micorrízico não encarece significativamente os sistemas.

No sistema 1, os insumos foram mais onerosos, principalmente devido a cultura do mamão, que contribuiu em média com 67% e 78% do total gasto para os tratamentos com 30% e 100% de adubação, respectivamente, enquanto a participação média da mão-de-obra em todos os tratamentos foi de 18%.

Nos sistemas 2 e 3, a diferença de custos de mão-de-obra entre os tratamentos de culturas anuais foi devida a aplicação de fungo micorrízico, que contribuiu com o aumento de 1 (uma) diária para cada cultura. Além disso, no sistema 2, os gastos com insumos foram maiores com culturas perenes, cerca de 90% para todos os tratamentos. Ao contrário do sistema 2, no sistema 3, as culturas anuais apresentaram, em média, 60% de custos para mão-de-obra e 66% de insumos.

No sistema 4, com essências florestais, os dados demonstraram custos totais de U$ 58.0, sendo aproximadamente de 50% o percentual de insumos e mão-de-obra.

Entre os monocultivos o mais oneroso foi o sistema 8, com pupunheiras, onde foram gastos U$ 517.7 com insumos e U$ 197.9 com mão-de-obra para uma parcela com 384 plantas.

As seringueiras (sistema 6), apresentaram gastos maiores com mão-de-obra, cerca de U$ 66.2, dos quais U$ 30.5 foram necessários para coroamentos, capinas e roçagens. As laranjeiras (sistema 9), ao contrário, gastaram U$ 82.6 com insumos e somente U$ 37.0 com mão-de-obra.

Para o sistema 7 (cupuaçu), foram necessários U$ 67.7 para implantação e manutenção, dos quais U$ 33.3 com insumos e U$ 36.4 com mão-de-obra, sendo que 56% foram gastos com coroamentos e roçagens.

Nos gráficos 1, 2 e 3, estão demonstrados os dados encontrados na tabela 1.

4 Considerações finais

Com os atuais dados dos custos de implantação e manutenção é difícil avaliar-se a perspectiva de viabilidade econômica dos sistemas testados, porém, é possível identificar alguns sistemas que poderão ser adaptados a diferentes níveis de produtores, dependendo dos meios de produção aos quais estes estarão sujeitos.

Os sistemas 2 e 3, onde existe a produção de culturas alimentares, identificam-se melhor com a realidade do pequeno produtor da região, tendo em vista a necessidade de subsistência da família. As culturas frutíferas surgem como uma alternativa de diversificação, tanto alimentar como de receita, uma vez que com essa espécies é possível, realizarem-se ao longo do ano, várias colheitas. Por serem perenes, as fruteiras estão mais próximas de adaptação a vegetação regional, caracterizada por mata permanente.

No entanto, para que isso seja implementado, é necessário que exista mão-de-obra familiar suficiente para manter o sistema, pois, como demonstram os dados, 60% dos custos de mão-de-obra, no sistema 3, foram com culturas anuais, e que o produtor tenha acesso a financiamento para aquisição de insumos, devido, principalmente, as características de baixa fertilidade dos solos da região.

A adaptação dessas espécies florestais ao baixo teor de fósforo dos solos da Amazônia sugere que o sistema 4, onde estão sendo testados mogno, andiroba, paricá e seringueira, com 30% da adubação recomendada, poderá ser uma alternativa com perspectiva de sucesso, a longo prazo, principalmente, porque esse sistema, quando comparado com os demais apresentou reduzidos custos de implantação e manutenção, podendo ser utilizado em áreas impróprias ao cultivo de culturas alimentares, as quais demandam muitos insumos, áreas de mata secundária e/ou abandonadas, que não oferecem retorno imediato.

Os monocultivos, exceto a pupunha, quando comparados aos policultivos, apresentam custos mais baixos, contudo o retorno é mais demorado, tendo em vista, nos policultivos existir a sazonalidade de produção. Esses sistemas são mais interessantes para médios e grandes produtores que possuem capital de investimento para plantio de grandes áreas e aquisição de mão-de-obra para manutenção, pois o percentual de capinas e roçagens é elevado.

Tabela 1:

Custos de implantação e manutenção de uma parcela dos sistemas no período de agosto 1992 à dezembro 1993

Sistema	Tratamento	Mão-de-Obra (U$)		Insumos (U$)		Total (U$)
		Plantas anuais	Plantas perenes	Plantas anuais	Plantas perenes	
1	30% c/ Mic		160,8		196,3	357,1
	30% s/ Mic		160,8		190,6	351,4
	100% c/ Mic		160,8		289,9	450,7
	100% s/ Mic		160,8		284,2	445,0
2	30% c/ Mic	36,9	80,3	8,8	86,9	212,9
	30% s/ Mic	30,9	80,3	8,8	83,2	203,2
	100% c/ Mic	36,9	80,3	12,6	109,0	238,8
	100% s/ Mic	30,9	80,3	12,6	105,3	229,1
3	30% c/ Mic	80,6	47,5	156,3	77,8	362,3
	30% s/ Mic	62,6	47,5	156,3	74,9	341,4
	100% c/ Mic	80,6	47,5	173,9	95,4	397,5
	100% s/ Mic	62,6	47,5	173,9	92,7	376,8
4	30% c/ Mic		29,4		28,6	58,0
6	100% s/ Mic		66,2		51,7	117,9
7	100% s/ Mic		36,4		33,3	67,7
8	100% s/ Mic		197,9		517,7	715,6
9	100% s/ Mic		37,0		82,6	119,6

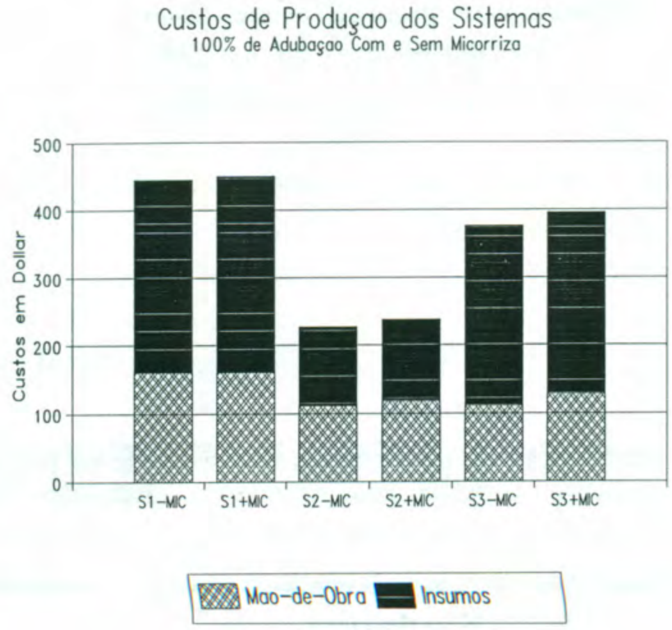

Gráfico 1:

Custos de produção dos sistemas com 100% de adubação com e sem aplicação de fungos micorrízicos

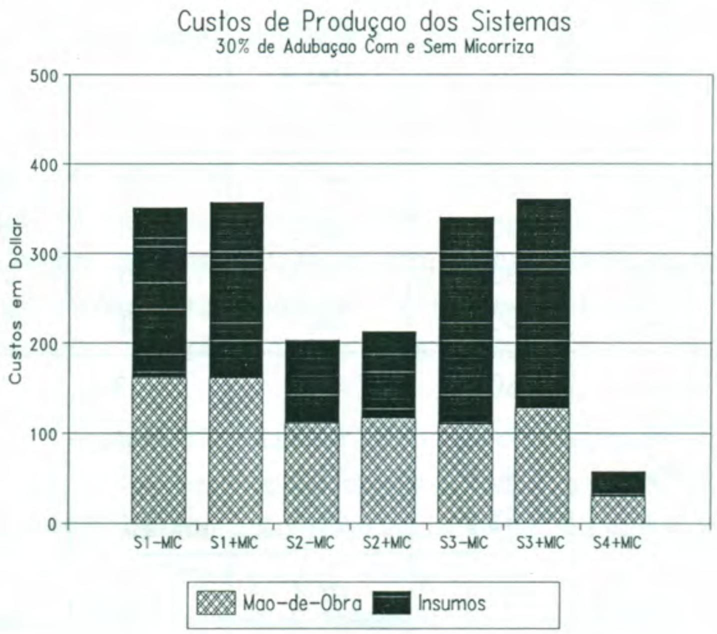

Gráfico 2:

Custos de produção dos sistemas com 30% de adubação com e sem aplicação de fungos micorrízicos.

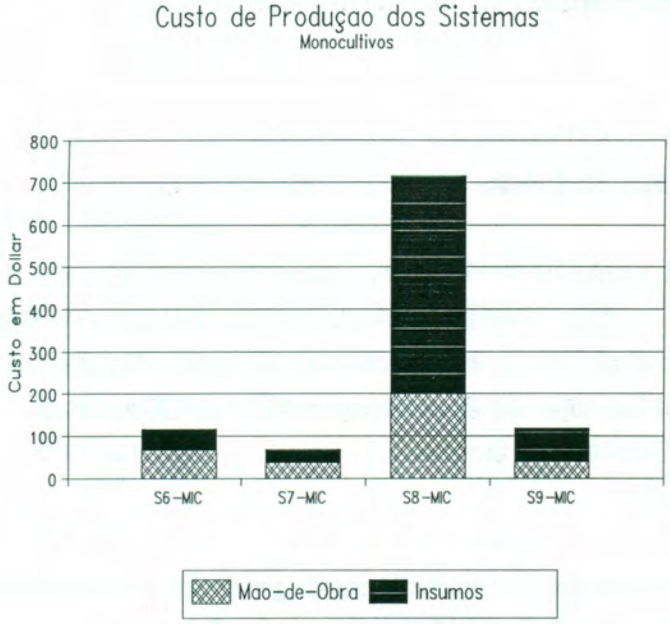

Gráfico 3:
Custos de produção dos Sistemas (monocultivos) com 100% de adubação sem aplicação de fungos micorrízicos.

Liste von Arbeiten, die auf Kongressen präsentiert wurden

A. 1st SHIFT-workshop in Belém-PA, 8-13 March, 1993

LIEBEREI, R., GASPAROTTO, L., PREISINGER, H., FELDMANN, F. & IDCZAK, E. 1993. Recultivation of abandonded monoculture areas in Amazonia. In: Junk, W. J. & Bianchi, H. K. (eds.): Studies on Human Impact on Forests and Floodplains in the Tropics (1. SHIFT-work-shop Belém, March 8-13, 1993), Geesthacht, Germany.

B. Sympósio "Manejo e reabilitação de áreas degradadas e florestas secundárias na Amazônia", 18 a 22 de abril de 1993 em Santarém-PA

FELDMANN, F., L. GASPAROTTO, R. LIEBEREI & H. PREISINGER: Utilization of abandonded areas in Amazonia by polycultures of perennial useful plants (Poster).

FELDMANN, F., I. MÜLLER, I., MACÊDO, J.L.V. & IDCZAK, E.: Preparo e aplicação de fungos micorrizicos em sistemas de polycultura na Amazônia (Poster).

FELDMANN, F., MÜLLER, I., WERITZ, MACÊDO, J.L.V. & E. IDCZAK: Isolamento, seleção e produção de fungos micorrízicos vesicular-arbusculares (FMVAs) e sua aplicação em sistemas de polycultivo (Poster).

FELDMANN, F., Müller, I., IDCZAK, E., NUNES C.D.M. & LIMA, M.I.P.M.: Sistemas de cultivos na Amazônia dependem do manejo dos fungos endomicorrízicos (Poster).

PREISINGER, H. & COELHO, L.F.: Análise da vegetação espontânea em uma área experimental agrícola (Poster).

SCHMIDT, P., LIEBEREI, R., BAUCH, J. & GASPAROTTO, L.: Balanço de bioelementos em plantas tropicais cultivadas (Poster).

C. Symposium "Tropische Nutzpflanzen", 22.-24. September 1993 in Hamburg, Deutschland

FELDMANN, F., PREISINGER H., GASPAROTTO, L. & LIEBEREI, R.: Economic potential of useful plants for the use in sustainable tropical polycultures in Amazonia (Poster). Abstracts 83.

FELDMANN, F., PREISINGER, H., GASPAROTTO, L. & LIEBEREI, R.: The environmental changes during field preparation in Amazonia require an ecologically adapted agricultural production system to reach economical stability (Poster). Abstracts 84.

IDCZAK, E. & FELDMANN, F.: Mycorrhizal status of an abandoned rubber tree plantation after slashing and burning (Poster). Abstracts 88.

LIEBEREI, R., FELDMANN, F., PREISINGER, H., GASPAROTTO, L.: Recultivation of degraded, fallow lying monocultural areas with equilibrated polyculture under special respect to soil microbiological factors (Poster). Abstracts 81.

MORAES, V.H. de F.: Native fruit species of economic potential in Amazonia (Brazil). Abstracts 22.

MÜLLER, I., HÖFNER, W. & GASPAROTTO, L.: Use of VAMF in tropical fruit production on abandoned areas in the Amazon (Poster). Abstracts 87.

NEVES, E.J.M. & CANTO, A. do C.: Selection of forestry species for the recovery of altered landscape in the Brazilian Amazon. Abstracts 85.

PREISINGER H. & FELDMANN, F.: Erprobung von Mischkultursystemen auf einem Terra-Firme-Standort Amazoniens. Abstracts 55.

PREISINGER H. & COELHO, L.: Recultivation of abandonded monoculture areas in Amazonia: Functional traits of the spontaneous vegetation in an experimental polyculture plantation (Poster). Abstracts 82.

SCHMIDT, P., LIEBEREI, R., BAUCH J., & GASPAROTTO, L.: Bilanzierung von Bioelementen in tropischen Kulturpflanzen (Poster). Abstracts 89.

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EMBRAPA / CPAA — UNIHH / IANGBOT

RECUPERAÇÃO DAS ÁREAS ABANDONADAS

SHIFT-Projekt ENV-23

Rekultivierung degradierter, brachliegender Monokulturflächen in ausgewogene Mischkulturflächen unter besonderer Berücksichtigung bodenbiologischer Faktoren

Förderkennzeichen 0339457A

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CONTENT

VA-MYCORRHIZA ENHANCES GROWTH AND HEALTH OF USEFUL PLANTS IN AMAZONIAN ABANDONED FIELDS

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BACTERIA ISOLATED FROM THE RHIZOSPHERE OF THE CUPUACU-TREE CAN BE GROWTH PROMOTING

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Summary

After the first 20 month of the current SHIFT-project "Recultivation..." the results of the already evaluated experiments show that the introduction of VA-mycorrhizal fungi was very successful. Growth and health of the useful plants were benefited by the mycorrhizal fungi. Reduced plant losses after planting nursery plants into the field and reduced quantities of fertilizer necessary for optimal growth of some useful plants indicate that the introduction of mycorrhizal fungi will result in an economical advantage.

In parallel experiments methods and strategies are developed to

to clarify the question how long the introduced mycorrhizal fungi survive under field conditions and in how far the effect caused by the introduced fungi sustains after their disappearence.

Beneath mycorrhizal fungi bacteria as very important elements of the rhizosphere were studied. From rubber tree and cupuacu-roots eleven species of rhizosphere bacteria were isolated and identified. In one case the microbes were shown to have growth promoting characteristics.

Introduction

The knowlegde about tropical ecosystems, about their delicateness, fragilness and internal network is very small. The low fertility of 90% of the soils in the tropical regions of Brasil are the largest handicap of agriculture and food production in a conventional sense in Amazonia (Frazao et al. 1982).

The handling of short nutrient cycles, leaching of nutrients on one hand, bad availability on the other hand, the importance of the heterogeneity of the natural plant cover, and the interactions between fauna, flora and microorganisms are not well known or understood so far.

The few data must be supplemented and put into practice rapidly to allow the prompt development of concepts for effective protection of the rainforest and simultaneous ensurance of the social and economic development of the region.

Traditional management of the rainforest as carried out by indigenous people in the Amazon basin (Boom, 1984; Dubois, 1982) are not practicable to feed large populations because they are of low output and depend on a semi-nomadic life cycle of the people.

A real resolution of the agricultural problems can only be found in a mixed cultivation of selected, perennial plants. They give the possibility to build up conditions similar to those which exist in the primary plant cover. The function of perennial trees as reservoires for nutrients and their role in the recyclisation of biomass in complex systems was demonstrated very often (e.g. Shubarth, 1977; Sioli, 1980; Burger, 1986). Especially in Amazonia a consequent use of these systems lacks.

If a recultivation of fallow lying areas or pastures in the Amazon region is planned one has to pay respect especially to pedological and soil-microbiological problems: all of the areas have been established by slashing the primary forest and destroying the soil structure and soil-microorganisms by burning. In nearly all cases the areas have been cleared mechanically afterwards, and were treated then with a high input of pestizides during the cultivation phase (Faßbender 1990). First soil-biological analysis in rubber tree plantations show that a dramatic change in the populations of the soil-microbes occured and that the plants became much more susceptible to stresses (Feldmann et al., 1994c).

The microbiological status of a soil is of greatest importance for the nutrient cycle and its biological quality (Safir et al, 1987). By inoculation of soils with mycorrhizal fungi (self-produced inoculum or collected soil from natural stands) an improvement of the soil is possible (Feldmann, 1991). Those studies indicated, that principally a recultivation of abandoned areas in spite of a present deficacy of symbionts is possible, if a management practice is developed, which includes treatments for the biological improvement of soils. For example useful plants which are mycotroph or living in symbiosis with N-fixing bacteria have to be used together with selected effective microorganisms (see also Feldmann and Lieberei, 1992 and Feldmann and Lieberei, 1994).

In the current project "Recultivation..." degraded fallow areas of former rubber tree plantations are being transferred into a location-adapted form of utilization considering especially the microbiological factors of the soil (Feldmann et al., 1993a, 1994c; Lieberei et al., 1993b; Appendix 1).

Following the fact of heterogeneity of natural plant communities mixed cultures of perennial trees were installed. The most of the tropical useful plants are highly dependend on mycorrhizal or bacterial symbiosis (St. John, 1985). The useful plant species chosen for this project were known to need the mutual symbionts in a different extent (Feldmann et al., 1993b, 1994a), too.

During the different phases of the project the indigenous populations of the most important mutual fungi, mycorrhizal fungi, are being registered. They are being quantified and characterized under the aspect of affecting the plants' growth and health.

Additionally to the mycorrhizal fungi rhizosphere bacteria are being evaluated for their potential usefulness in meliorationg the plant growth. Potentially antagonistic organisms are being studied as well (Collembola).

Next to the studies on indigenous growth promoting microbes an inoculation of useful plants under nursery conditions and in the field is being done. Investigations on the mycorrhizal effect in practice on one hand and on the survival of introduced fungi on the other hand are carried out.

Studies on the population dynamics of introduced mycorrhizal fungi requiere methods to observe the used fungi in the habitat or in the useful plants planted in the field. To adapt such methods to the concrete situation is another important field of research under the topic of soil microbiological aspects of the project.

In this contribution the current experiments and the already collected - or even published - data are demonstrated.
The aspect of field inoculation of mycorrhizal fungi and studies on the expansion of root systems is published elsewhere in this volume by *Idczak* and *Voß.*
Further investigations on N-fixing Rhizobia and other soil microorganisms are reported by *Oliveira* and his group in this report, too (*Oliveira & Moreira, Figueiredo & Oliveira, Farias & Oliveira*).

See also Appendix 1: Feldmann et al., 1993a, 1994c

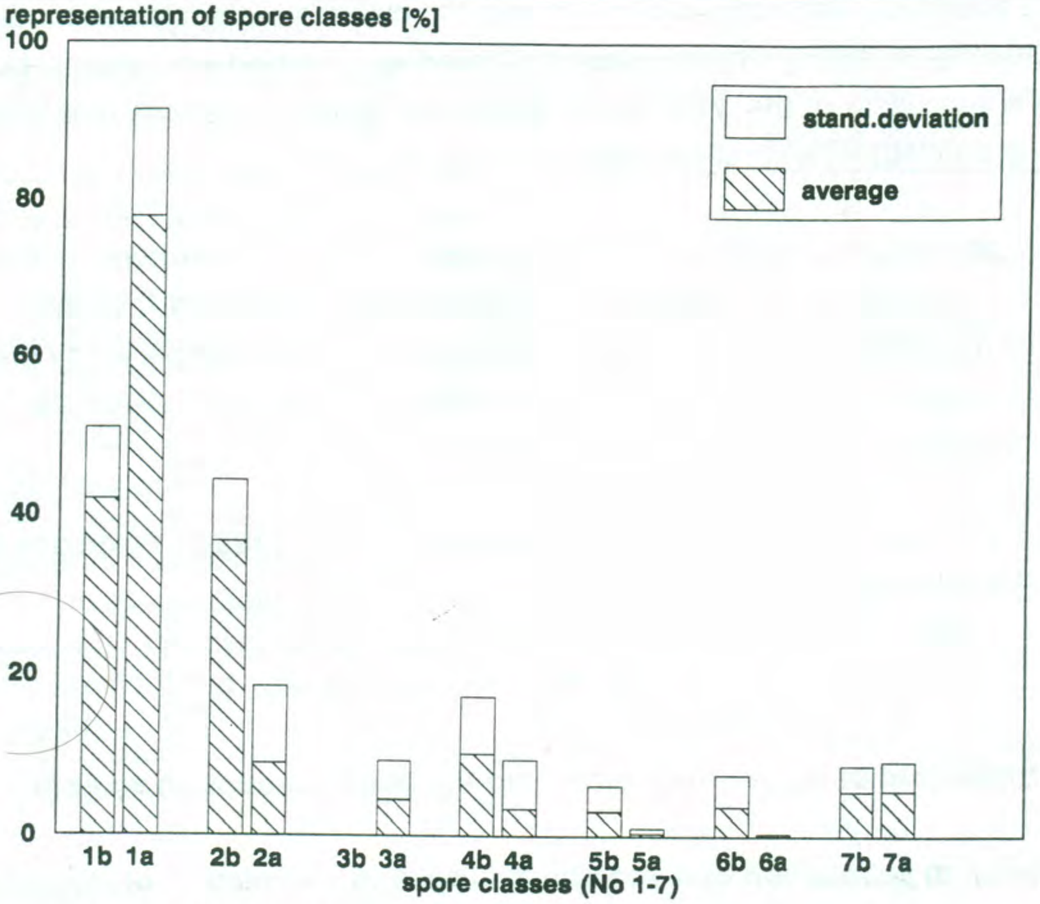
Results

1 Mycorrhizal situation before and after burning of the experimental area

In Amazonia the burning of the primeval forest and the clearing of the sites by use of dredges eliminates most of the symbiotic microorganisms and the nutrient enriched upper layer of the soils.
Recent soil-biological data demonstrated without doubt, that the indigenous populations of microorganisms are desturbed by such a treatment of a plantation (Feldmann and Lieberei, 1994). The populations were apparently not regenerating over a long time. Feldmann (1991) and Feldmann and Lieberei (1991) compared the populations of VA-mycorrhizal fungi from natural stands of the rubber tree and from rubber tree plantations. Even ten years after the conventional installation of the monoculture these mycorrhizal populations did not regenerate (Feldmann et al., 1993c).
During the installation phase of the project "Recultivation..." a more moderate method of clearing was carried out: after burning the remaining stems of the vegetation were removed by hand. But nevertheless we found an extreme negative impact of the fire to the mycorrhizal populations in the soil (Idczak and Feldmann, 1993, Appendix 2).

For a second time an analysis of the composition of the VAM-fungal comunities was made six months after burning. Detailed information about this second sampling is given by *Idczak*.

Figure 1: Spore classification before and after burning of the experimental fields



spore classification:

class 1: yellowish/brown, 70-100μm, oval "Glomus a"
class 2: yellow, 100μm, round "Glomus b"
class 3: hyaline, 60-80μm, oval "Glomus c"
class 4: hyaline/yellowish, 55μm, round "Scutellospora a"
class 5: hyaline/white, 460μm, round "Scutellospora b"
class 6: brown, 550μm, round "Acaulospora sp."
class 7: others

The detailed sampling and evaluation procedure is described by *Idczak*

As we demonstrated in Appendix 2 only very few mycorrhizal fungi which colonized host plants selectively and very weakly survived the clearing of the plantation. But not only the quantity of the symbionts was influenced by the field preparation but the qualitative composition of the VAM-fungal comunities changed as well (analysed six months after burning). The results are shown in Fig. 1.

14 months after clearing and burning *Figueiredo & Oliveira* observed that some elements of the spontanous secondary vegetation in the meanwhile had been colonized by mycorrhizal fungi. It must be proven now if this was supported by the field inoculation of mycorhizal fungi or if some components of the indigenous fungal community did regenerate.

For detailed information see also Appendix 2: Feldmann et al., 1994c; Feldmann et al., 1993c; Idczak & Feldmann, 1993

2 Introduction of mycorrhizal fungi into the plant production system

2.1 Inoculum production of mycorrhizal fungi and inoculation of mycorrhizal fungi

The starter inoculum of VA-mycorrhizal fungi was produced in Hamburg already in 1992 on expanded clay as carrier material (Feldmann et al, 1993c; Feldmann and Idczak, 1992; Appendix 3). In Manaus sand and soil from forest stands was used as substrate (reported in Lieberei et al., 1993c); the inoculum was produced in wooden boxes of 0,3x1x1m extension. That mass-production in Manaus resulted in sufficient inoculum for all nursery-inoculations. The origin of the used fungal strains are described in Table 1.
For the field inoculations of annual and biannual plants (Zea mays and Manihot esculenta) expanded clay was used. That inoculum had to be produced in Hamburg and was sent by ship to Manaus.
The application procedure was described by Lieberei et al, 1993d and Feldmann et al., 1994e (Appendix 3).

Table 1: VA-mycorrhizal strains used in the described experiments

species name	isolate no.	developed from the original isolate
Glomus etunicatum	HH6, HH13 HH329	T6, D13 Dehne Gletc 329 INVAM
Glomus intraradices	HH208, HH276	Glinr 208+276 INVAM
Glomus manihotis	HH1, HH2	Wer1 + 2 Weritz
Acaulospora spec.	HH12	Sym12 Weritz

The original isolates of mycorrizal fungi were provided by Dr. Weritz, Symbionta, Gifhorn, FRG, Dr. Dehne, Bayer, Leverkusen, FRG and Dr. Schenck, International Collection of VA-mycorrhizal Fungi, Gainesville, USA. After 6 years of cultivation under standardised conditions stabil strains with certain characteristics have developed.

2.2 Development of mycorrhiza in the root systems of the useful plants before planting and response of the useful plants to mycorrhizal inoculation

Positive growth response of the useful plants
to VAM inoculation in the nurseries

The most of the perennial plant species used in this project were self-produced from seeds or vegetatively by stem- or root-cuttings. All these plant species were inoculated with mycorrhizal fungi while planting them into plastic bags. They received 1-5 VAM-infection units/cm^3 of the not sterilized substrate. In average four months later the plants were planted into the field. Only some species had to be bought from other nurseries (e. g. Cocos nucifera), had to be produced in a shorter time period (e.g.

Carica papaya) or were planted as cuttings directly into the field (Manihot esculenta) and therefore differed in the inoculation process (growth response see Fig. 1).

Figure 1: Growth response of nursery grown useful plants after VAM inoculation (difference [%] in height)

Plant species	growth response (height) difference [%] to plants without mycorrhizal inoculation	degree of VAM root colonization with and without inoculation [%]	
		M +	M-
Schizolobium amazon.	0,3	61 (7)	26 (1)
Bixa orellana	7,0	59 (10)	31 (18)
Cocos nucifera	7,0	#	0
Hevea brasiliensis	9,6	##	##
Theobroma grandifl.	10,0	1 (0,7)	0
Bertholletia excelsa	14,7	<1	0
Bactris gassipaes	15,0	0	0
Carapa guianensis	28,9	9,5 (5,3)	42 (16,9)
Swietenia macrophyl.	36,4	35 (19)	8 (4)
Manihot esculenta	51,0 *	52 (15)	0
Carica papaya	70,0 *	46 (12)	0

All plant species except * marked species were inoculated in nurseries and grown in average four months in plastic bags before they were planted into the field. The results of * marked species were collected in parallel green house experiments. The average degree of root colonization by VAM fungi was estimated in only few, randomely chosen samples of each species; the values for root colonization therefore give no representative information. The values in parentesis are standard deviations (n>3). # Cocos nucifera was inoculated only few days before planting; ## Hevea did not form an intensiv fine root system during the preparation phase.

Nearly all perennial plant species showed a positive growth response due to mycorrhizal inoculation. The height of the effect was not correlated with the degree of root colonization. E.g. the low response of Schizolobium amazonicum was not due to missing VAM-mycorrhizal fungi (61 $\pm$ 7% root colonization). The introduced fungi obviously competed in 8 of 10 cases successfully with the indigenous fungi; the degree of root colonization was higher in inoculated treatments than without inoculation. In one case (Carapa guianensis) the root colonization was much lower with inoculation of mycorrhizal fungi than without. But even in this symbiosis a positive growth response of 28,9% height enhancement could be observed.

From former results during the selection phase of the VAM-fungi we know that the data shown here can be even higher if the time period in the nursery is prolonged. But

because of the season it was necessary in this case to plant the useful plants in the shown state of development into the experimental field.
Further, more detailed investigations will follow on this subject to clarify the interrelationships between root colonization, effect and fungal competition.

Enhanced production of corn due to the inoculation with VAM fungi in a field trial

Four different plant mixtures were outlayed (see Tab. 3) in five repetitions (Plot A-E). In planting system III (compare Tab. 3) between the rows of the perennial plants in the first year Zea mays as acrop with rapid return was sawn; 50-100 infection units, bound to expanded clay particles (Feldmann and Idczak, 1992) was brought in direct contact to the corn seeds.
After ripening the yield was evaluated (Tab. 4).
The comparison of the treatments without mycorrhizal inoculation (30%/NM and 100%/NM) shows a very low fertilization efficacy: 70% more fertilizers result in only 22% more yield. If mycorrhizal fungi are introduced together with the low fertilizer dosis (30%/M) the difference to the treatment with the recommended fertilizer dosis (100%/NM) is even smaller: 70% more fertilizer result in only 12% more yield.
The inoculation of VAM-fungi at recommended fertilizer dosis (100%/M) gives the bests results: in average 37% more yield than in the treatment 100%/NM without mycorrhizal inoculation and even 59% more yield than in the low fertilizer/no inoculation treatment (30%/NM) which means 70% more fertilizer result in 59% more yield, if VAMF are inoculated.
Besides these economical aspects a more detailed analysis of the interrelationships between introduced fungi, indigenous fungi, fertilization dosis and corn yield is interesting from a biological point of view.
As well in Tab. 4 the root colonization of corn in the different plots and treatments is demonstrated.
Without introduction of mycorrhizal fungi (100%/NM and 30%/NM) the indigenous VAM fungi colonize in average 23,5% $\pm$ 16,1% of the root system of corn. The values for yield and the degree of root colonization are not correlated (corr = 0,37). In those

treatments as well no correlation between the amount of fertilizers and the root colonization by mycorrhizal fungi can be observed. It seems that the height of the current indigenous inoculum potential is decisive for the degree of colonization.

Table 2: Corn yield, fertilization and mycorrhizal status of Zea mays in the field

	Parameter	Plot A	Plot B	Plot C	Plot D	Plot E	Average
100%/NM	yield [kg/ha]	661,0	435,0	538,0	557,0	315,0	501,2
	yield [%]	100,0	100,0	100,0	100,0	100,0	100,0
	VAM colon. [%]	18,0	12,0	35,0	66,0	55,0	24,6
	spores [n/cm3]	9,9	6,8	5,8	3,8	6,1	6,5
	spore dist.-ratio	1,2	2,5	2,1	1,3	3,2	2,1
100%/M	yield [kg/ha]	775,0	630,0	653,0	838,0	483,0	675,8
	yield [%]	117,0	145,0	121,0	150,0	153,0	135,0
	VAM colon. [%]	3,0	27,0	6,0	63,0	24,0	20,8
	spores [n/cm3]	5,0	7,8	4,5	5,7	3,7	5,3
	spore dist.-ratio	1,5	2,3	1,1	1,9	1,2	1,6
30%/NM	yield [kg/ha]	479,0	305,0	538,0	497,0	258,0	387,6
	yield [%]	73,0	70,0	92,0	72,0	82,0	77,0
	VAM colon. [%]	21,0	17,0	26,0	35,0	13,0	22,4
	spores [n/cm3]	6,4	9,0	5,1	5,5	7,1	6,6
	spore dist.-ratio	0,5	0,9	0,4	1,4	1,5	1,0
30%/M	yield [kg/ha]	460,0	436,0	548,0	358,0	320,0	424,4
	yield [%]	70,0	100,0	102,0	64,0	102,0	85,0
	VAM colon. [%]	64,0	55,0	34,0	66,0	55,0	54,8
	spores [n/cm3]	4,5	7,7	4,6	4,6	5,1	5,3
	spore dist.-ratio	1,5	2,3	3,5	1,3	2,6	2,3

The corn plants were sawn between the rows of planting system III (compare Tab. 3). The mycorrhizal survey took place already four weeks before harvest. "100%/NM", "30%/NM" significates "recommended dosis of fertilizers" respectively 30% of it, no mycorrhizal inoculation; "100%/M", "30%/M" are the treatments with inoculation of mycorrhizal fungi (see Tab. 5). "Spore dist.-ratio": number of spores near the shoot compared with the spore number between two rows of maize.

The inoculum potential includes mycorrhizal spores and other propagules, e.g. mycelia. The number of spores is not correlated with the degree of root colonization, too (Tab. 4). The inoculum potential was estimated to be very heterogenous between the single plots (Idczak and Feldmann, 1993).

Comparing the root colonization in the treatments with inoculation of mycorrhizal fungi (30%/M and 100%/M) one observes a degree of colonization in the 100%/M treatment which is as high as in the non-inoculated treatments (20,8% ± 8,7%), but a dramatically increased colonization in the 30%/M treatment (54,8% ± 11,8%). Surprisingly the quantitatively unchanged degree of colonization in the 100%/M treatment was accompanyied by an increase of yield up to 53%. This circumstance indicates a qualitative change in the mycorrhizal roots of the 100%/M treatment, possibly a colonization by the inoculated VAMF fungi or at least an inhibition by competition of the root colonization by ineffective indigenous fungi (compare Feldmann et al., 1993).

The much higher degree of root colonization by VAM fungi in the 30%/M treatment points out two things: the introduced fungi are probably negatively influenced by an increase of fertilizer dosis (compare Feldmann and Lieberei, 1992) and the effectivity of the symbiosis is not linearely correlated with the degree of colonization by VAM fungi.

The demonstrated data show that a strong competiveness of both indigenous and introduced fungi may be one of the most decisive criteria in a plant production system as installed here.

For further information about the development of the VAM-spore community, and the "nurse plant effect" see *Idczak*.

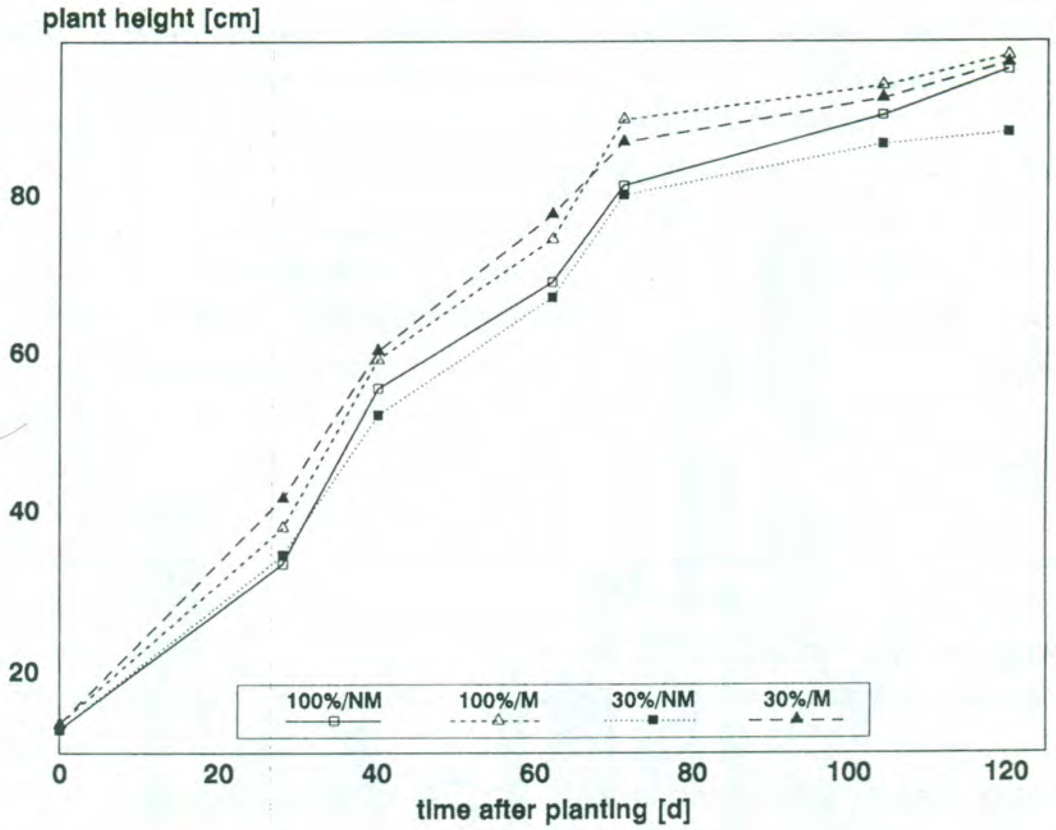
Positive response to VAM of a perennial crop (Carica papaya) under field conditions

Carica papaya is a plant which shows a strong growth response to VAM inoculation when grown in greenhouses or nurseries. (Fig. 1).

If greenhouse grown papaya plants are planted into the field, already being extremely different in growth from non-mycorrhizal plants, the mycorrhizal plants continue growing better under field conditions and give better yield later (Müller and Höfner, 1993). The effect in the field is therefore a consequence of being ahead of the non-mycorrhizal plants.

In order to test the potential capacity of introduced mycorrhizal fungi under field conditions without such an advantage for the host plant, we outlayed the following experiment:
Carica papaya grows very rapidly, but the growth of the upper plant parts is strictly correlated with the development of the root system. This gives the possibility to limit the growth of the plant by restricting the root growth using very small pots in the preparation phase of the plants. Following this method, we could plant papaya seedlings of the same height, mycorrhizated or not, all over the 19ha field in spite of the fact that they were not planted on the same day. In Fig. 2 the growth of inoculated and not-inoculated papaya plants is demonstrated.
Already a few days after planting the mycorrhizal plants overtoped the not-inoculated plants (up to 12,5% of height). This was true for both mycorrhizal fertilizer treatments (100%/M and 30%/M). The development of both mycorrhizal treatments was equal, apparently not limited or promoted by lower fertilizer dosis.
The not-inoculated treatments remained smaller than the inoculated plants but also developed identically up to 70 days after planting. 120 days after planting the plants of the 30%/NM treatment differed already 9,1% of height from the plants of the 100%/NM treatment, while those plants reached the height of the VAM-inoculated treatments.
The comparison of the growth of papaya seedlings in the different treatments indicates that the development of papaya seedlings is probably triggered by the plants' own capacity for nutrient uptake and by the amount of available nutrients: Both fertilizer treatments without mycorrhizal inoculations grow in the same extent. The difference between the two non-mycorrhizal treatments three months after planting may be caused by a starting defizit of available nutrients in the low fertilized treatment. In this hypothesis an early mycorrhization would lead to an enhanced ability to take up nutrients from the substrate correlated with better growth. If the equality of height between the mycorrhizal treatments and the treatment 100%/NM is due to the loss of the introduced mycorrhizal fungi or the colonization of the roots of the 100%/NM treatment by effective indigenous VAM fungi is presently studied. Recent data shown by Idczak (p.55, Fig. 3) indicate such interrelationships between competing fungi.

Figure 2: Growth of inoculated and not-inoculated Carica papaya seedlings under field conditions

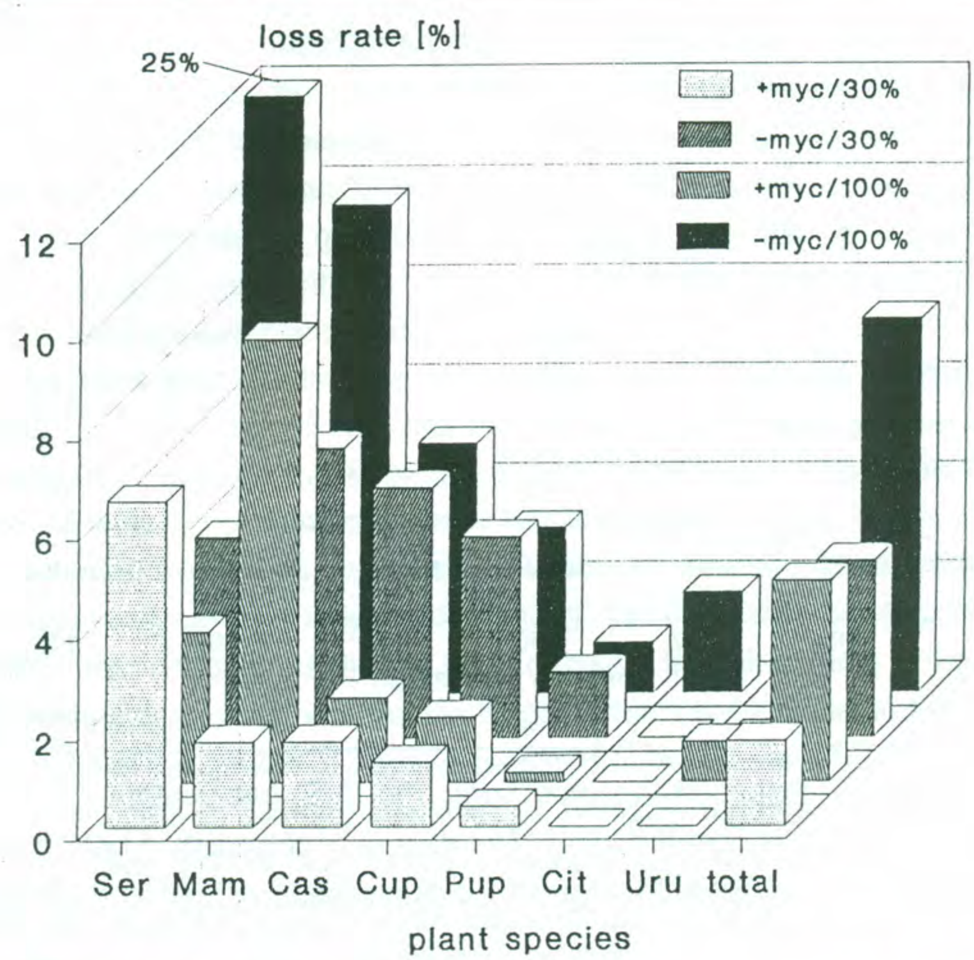


The cited values are means of five repetitions (Plot A-E) per treatment. The Least Significance Difference is 5cm (LSD5%). The degree of colonization before planting was 42 $\pm$ 23% in the inoculated treatments, no colonization without inoculation.

Lower loss rates of useful plant species after planting

The rate of plant loss during the preparation and establishing phase of a recultivation process can be economically decisive for the success of the project. Already during the preparation of the plant material in the nurseries there are plant losses which have to be minimized by using the adequate management practices. But even the best plant material is threatened by the stress of planting into the field.

Figure 3: Loss rates [%] of seven plant species three months after planting



Abbreviations: Ser Hevea brasiliensis; Mam Carica papaya; Cas Bertholletia excelsa; Cup Theobroma grandiflorum; Pup Bactris gassipaes; Cit Citrus sinensis; Uru Bixa orellana. Number of plants see *Lieberei et al.* Fertilizer/Mycorrhizhal treatments: -myc/100% = 100%/NM; +myc/100% = 100%/M; -myc/30% = 30%/NM; +myc/30% = 30%/M; explanation see text above.

In the following experiment the best plants of the treatments shown in Fig. 1 and 2 were planted into the field (Tab. 3). In order to measure the influence of the management factor "mycorrhizal inoculation" after three months of growth the loss rate of the useful plants was calculated (Fig. 3).

Due to the management practices during the preparation phase and the selection of the plants for planting into the field the loss rates of the most of the plant species in the commonly recommended management treatment were very low. But in some species up to 25% plants were lost after planting (e.g. Hevea brasiliensis).

The comparison of the four treatments 100%/NM, 100%/M, 30%/NM, and 30%/M demonstrates first that the application of only 30% of the recommended amount of fertilizers without inoculation of mycorrhizal fungi in some cases reduces the plant loss, too (Hevea brasiliensis, Carica papaya, Citrus sinensis), or does not influence the number of lost plants (Bertholletia excelsa, theobroma grandiflorum), but did not enhance the plant loss in any case.

The introduction of mycorrhizal fungi gave equally better positive results in both fertilizer treatments (Bertholletia excelsa, Theobroma grandiflorum, Bactris gassipaes, Citurs sinensis), or only together with the low fertilizer treatment (Carica papaya, Bixa orellana). In one case (Hevea brasiliensis) the smallest loss rate of all treatments was measured in the 100% fertilizer treatment with introduced mycorrhizal fungi while in the 30%/M treatment the double number of plants was lost than in the 100%/M treatment.

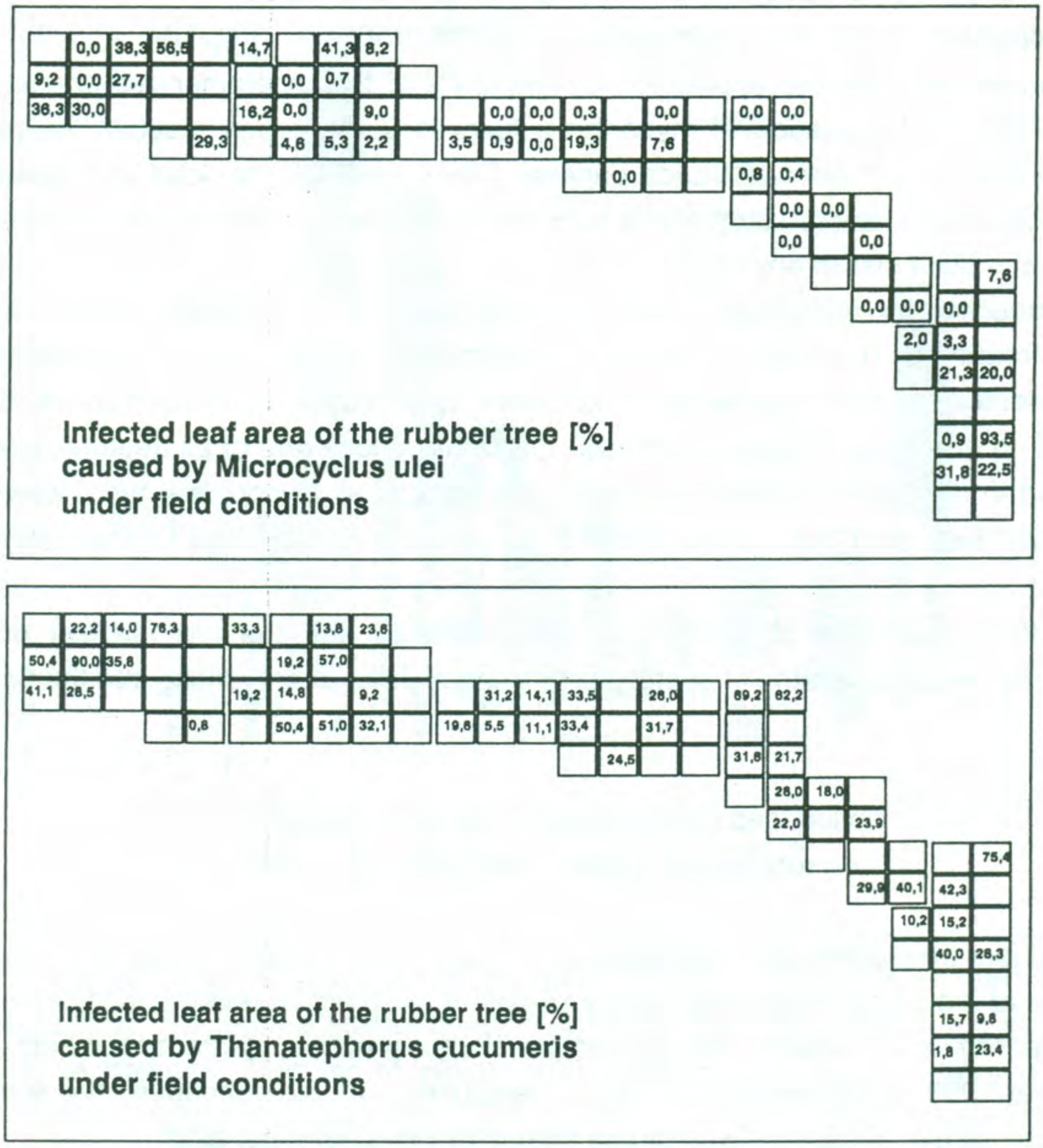
In total the introduction of mycorrhizal fungi together with the low fertilizer dosis showed the lowest loss rates of useful plants three months after planting into the field.

Influenced epidemiology of leaf spot diseases on rubber tree leaves under field conditions

Young rubber tree leaves are threatened by some leaf spot diseases which can cause the death of the plants especially in early stages of the plant development. The report of *Gasparotto et al.* shows the pathological situation of the plantations during the whole year 1993. In this contribution only an evaluation of data concerning the spread of Microcyclus ulei in the first five months after planting is demonstrated.

As it was already shown by Feldmann et al.(1989, 1991) and Feldmann (1990) that mycorrhizal rubber trees have more resistant leaves against the Ascomycete Microcyclus ulei (rubber tree leaf blight) than non-mycorrhizal plants, we observed the epidemiology of the rubber tree leaf blight in the experimental fields by evaluating the infected leaf area of the plants. At the same time the spread of the severe foliar pathogen Thanatephorus cucumeris was monitored but not discussed here.

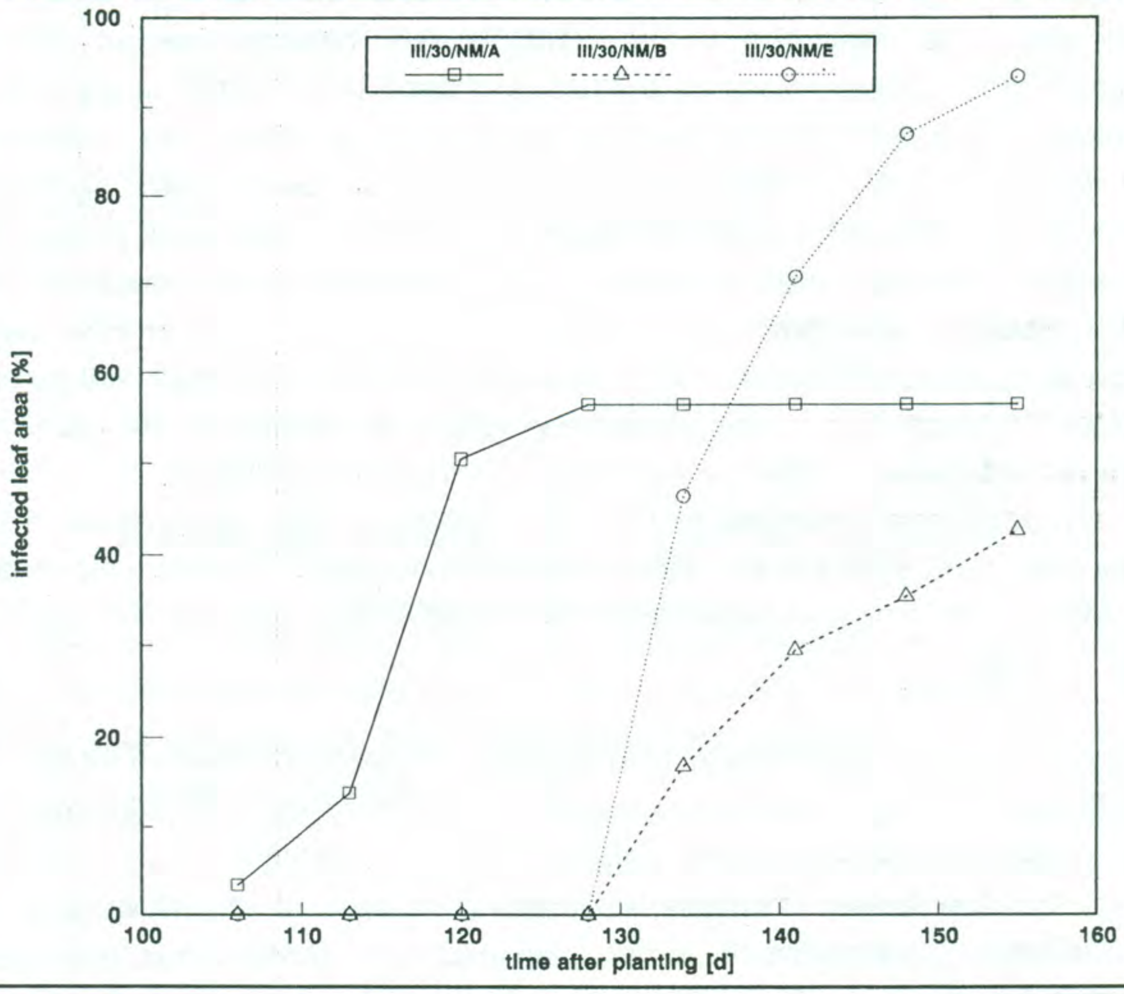
Figure 4: Distribution of the rubber tree leaf blight caused by Microcyclus ulei over the experimental fields 155 days after planting of rubber tree plants



The cited values are average degrees of leaf infection. Plots without value do not contain rubber trees. The average degree of infection was calculated on the base of 3-5 plants per plot.

In Figure 4 the average infected leaf area of rubber trees in each single plot is cited. Comparing the values within a block no gradient of the infection intensity can be observed. Plots with heavily infected plants are located beneath plots with only very few or even no rubber tree leaf blight. Nevertheless the maximum infection of the plots indicate a gradient of the degree of infection exists between block A (high infection) and D (very low infection). In contrast to block D rubber trees in block E have the highest infection of the whole plantation.

Figure 5: Epidemiology of the rubber tree leaf blight in the planting system III



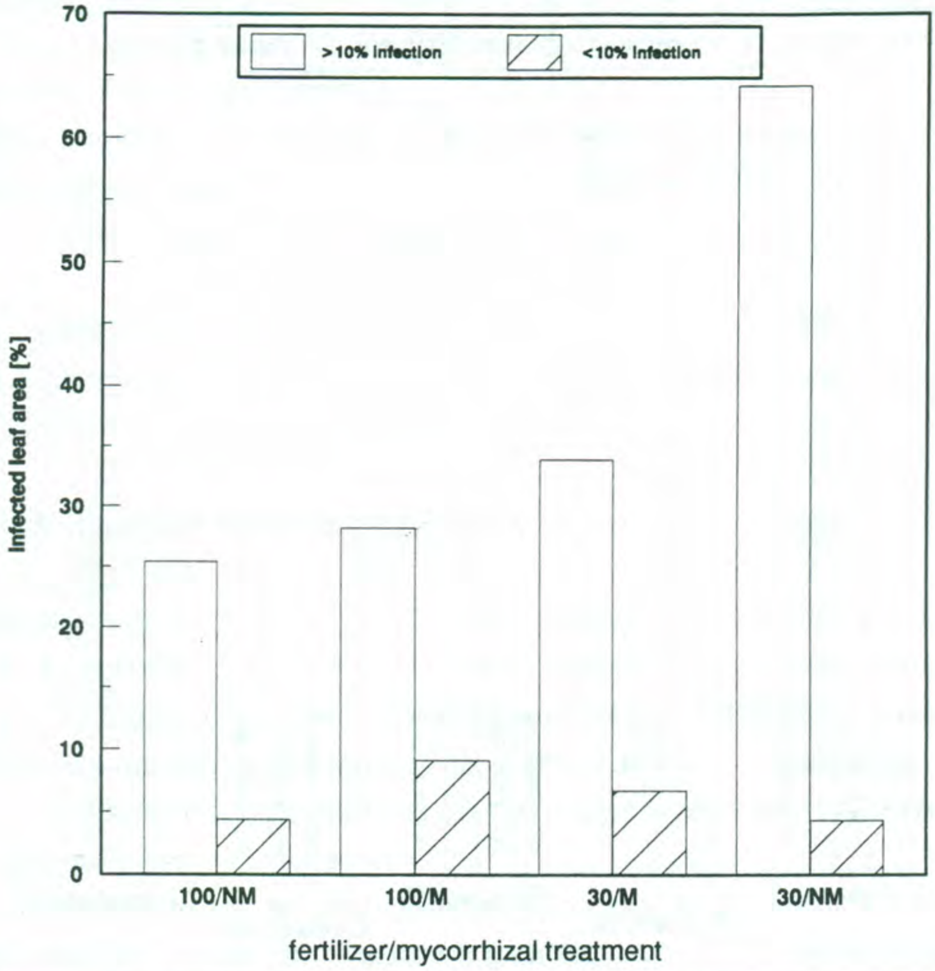
The cited values are average degrees of leaf infection. The average degree of infection was calculated on the base of 3-5 plants per plot. In this figure no differenciation into the different treatments was carried out. Only the planting system III was evaluated.

If the epidemiology of the rubber tree leaf blight (RTLB) is observed over the five months within a single treatment one can see that the epidemy started in block A and then continued at the same time in block B and E (see Figure 5). While in block B the final degree of infection reached nearly the height like found in block A, the degree of infection in block E was finally much higher than in block A. Probably the epidemy of Microcyclus ulei was not supported by the source in block a but by a further source outside the plantation, possibly the recent rubber tree monoculture nearby the experimental fields.

If sufficient pathogenic inoculum is available, the rubber tree leaf blight occurrs. As shown above the distribution of the RTLB is very heterogenous all over the experimental field. Nevertheless an evaluation of the RTLB situation in the different treatments "100%/NM" (100% recommended fertilizer dosis, no mycorrhizal inoculation), "100%/M" (100% recommended fertilizer dosis, with mycorrhizal inoculation) and 30%/NM and 30%/M respectively shows a clear result (Figure 6): if plots without or very low infection and those with higher infection are devided into two infection classes, in the 30/NM treatment a nearly three fold higher infection than in the 100/NM is evident. It seems as if the reduction of the recommended fertilizer dosis enhances the susceptibility of the rubber trees against M. ulei. Indeed the 100/M (with mycorrhizal inoculation) shows the same result (statisticly not different).
The very interesting measures in the 30/M treatment then demonstrate a high influence to the resistence of the rubber tree leaves: in spite of the low fertilizer dosis the VAM inoculated plants have only the half infection level than the non-inoculated 30/NM treatment.

A differentiation of these findings into the four planting systems containing rubber trees (No I, III, IV, and VI) gives further information (Fig. 7). In system I the 30/M treatment could compensate the fertilizer effect only partially. This finding is therefor correlated with the fact that system I contains few useful plant species, especially no annual plants. In contrast in the system III the infection level in the 30/M plot was lower than in the 100/NM plot and significantly lower than in the 30/M plots of the other planting systems.
In the planting system VI (rubber tree monoculture the infection level is higher than in the mixed cropping systems.

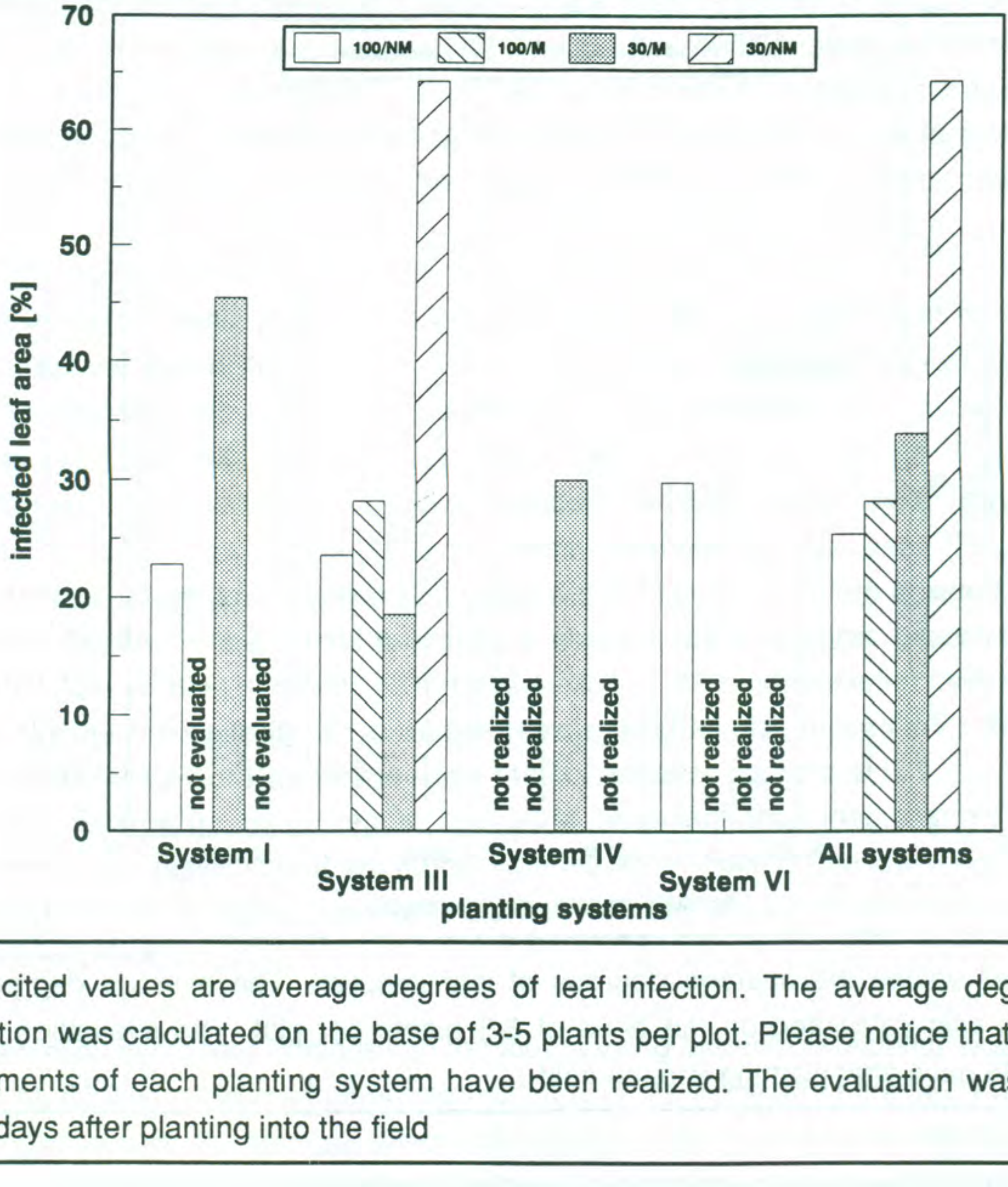
Figure 6: Degree of infection of rubber tree leaves caused by M. ulei in the different fertilizer/mycorrhizal treatments



The cited values are average degrees of leaf infection. The average degree of infection was calculated on the base of 3-5 plants per plot. The evaluation was done 155 days after planting into the field

To summarize the results between treatment/planting system/epidemiology in the field the following conclusions can be drawn: a) a interrelationship between fertilization and susceptibility of rubber tree leaves is probable. b) the localisation of the M. ulei source as inoculum was obviously decisive for the epidemiology of the pathogen all over the experimental field. c) the inoculation of the rubber trees in nurseries lead to significant changes in the resistance behaviour of the plant: lower fertilization did not lead to higher susceptibility.

Figure 7: Degree of infection of rubber tree leaves caused by M. ulei in the different planting systems containing rubber trees



The cited values are average degrees of leaf infection. The average degree of infection was calculated on the base of 3-5 plants per plot. Please notice that not all treatments of each planting system have been realized. The evaluation was done 155 days after planting into the field

3 Studies on the effectivity and recognition of mycorrhizal strains

The first results on the response of useful plants to mycorrhizal inoculation shows that there must exist several specific interactions between the VA-mycorrhizal fungi and the plant partners of the symbiosis.
Those interactions make it difficult to decide whether mycorrhizal fungi which have been introduced were effective or not, how long they persisted in a field, if they didn't have the ability to survive or if it would result in better success if other fungi would be selected.
The most of the questions could be answered if one would have a standardized system for testing the effect of mycorrhizal fungi and methods to recognize introduced fungi in the field.

3.1 In vitro-culture of mycorrhizal fungi

Testing the effect of mycorrhizal fungi under standardized conditions means that the test has to be carried out without the very important factor "soil bacteria", which normally are transported on the surface of each single mycorrhizal fungus spore. If potentially growth promoting or repressing bacteria are not excluded the test system, the measured effect must not necessarily be due to the mycorrhizal fungi, but be supported or repressed by the bacteria.
Therefore we tried to adapt several methods to our demands. Working on her Diplom-thesis (not financed by the BMFT, but by the IAngBot) T. Mohades installed in vitro cultures of the two useful plant species Petroselinum crispum and Solanum tuberosum. Under sterile conditions the mycorrhizal fungus Glomus etunicatum unfortunately did not germinate and colonize the root systems of the two plant species, although the spores were proven to be living and able to colonize the roots of the plants under not-sterile conditions.
These preliminary results will be reproduced and checked in 1994 again.

3.2 Production of antibodies against Glomus etunicatum and Glomus intraradices

The recognition of mycorrhizal fungus strains by their spore morphology is impossible. Therefore methods have to be adapted which are biochemically able to detect the mycorrhizal fungi even if they are inside a plant root.

One of the appropriate methods to recognize organisms is the use of antibodies against these organisms.

In 1993 the production of fungal inoculum together with roots of Petroselinum crispum started in order to get material for the production of polyclonal antibodies against two strains of Glomus etunicatum and one strain of Glomus intraradices. In the meanwhile the material is harvested and the production started in December 1993. The antibodies will be produced in cooperation with PD Dr. J. Voigt, Technical University of Braunschweig, FRG. The work is only partially financed by the BMFT.

3.3 Utilization of isoenzymes for indentifying mycorrhizal fungi

Since several years it is principally possible to descriminate VA-mycorrhizal species from each other by determining spectra of isoenzymes of the fungi. In November 1993 W. Kruse started with his Diplom-thesis (only partially financed by the BMFT) on the description of isoenzymes of a useful plant in presence of the mycorrhizal fungus Glomus etunicatum. We hope that we can recognize the specie Gl. etunicatum within the root system of a plant after that Diplom-thesis.

In Manaus already now plant material which was exclusevily inoculated with Gl. etunicatum (Carica papaya) and planted into the field afterwards is being sampled for later biochemical evaluation.

3.4 Preparation of mycorrhizal DNA for the use in fingerprint techniques

The analysis of DNA is a powerful method to descriminate even strains of fungi from each other. In mycorrhizal fungi this method works, too, but is presently tested only in the descriminiton of species.
In 1993 we tried to prepare DNA from mycorrhizal fungi (not financed by the BMFT) following the method described by Wink et al.,1990, and Swatschek et al. (in press). First results are presently evaluated and repeated.

3.5 Single spore isolates

For the evaluation by the described biochemical methods and for use in the standardized testing system 124 single spore isolates have been established; they are already passing the 3rd plant generation. All of these isolates are presently cultivated on Petroselinum crispum in Hamburg. They will be evaluated biochemically at the end of 1994.

4 Bacterial microorganisms of the rhizosphere

4.1 Isolation and identification of rhizosphere bacteria from Theobroma grandiflorum and Hevea brasiliensis

Introduction

Interactions with rhizosphere microorganisms (RMO) are of high importance for useful plants. Under certain conditions the presence of RMO can be decisive for the survival at the plant's stand.

The most important mutual RMO are mycorrhizal fungi and bacteria which enhance the availability of nutrients (e.g. N and P) for the plants.

In tropical agricultural systems the necessity of quick and effective nutrient recyclization can lead to dramatic growth reductions if RMO. It has already been shown that mycorrhizal fungi are missing in such tropical plant production systems (Feldmann, 1991). It is therefore of great interest to understand which role RMO play in specific plant/RMO interrelationships, i.e. to which extent plants depend on the presence and function of RMO.

The knowledge about that importance of RMO for useful plants is necessary to decide whether RMO should be included as management factors into plant production systems or could be neglected.

In Amazonia - under field conditions - the rubber tree (Hevea brasiliensis) was already described to be obligately mycotroph and dependend on VA-mycorrhizal fungi (Feldmann, 1991); growth and resistance reaction of leaves and roots are influenced positively by the root symbionts (Feldmann et al., 1989; Feldmann, 1991). Today the utilization of VA-mycorrhizal fungi is tested in field scale in Amazonian polycultural plantations and nurseries (Feldmann et al, 1993a) within the current SHIFT-project.

In contrast to the rubber tree the cupuacu tree (Theobroma grandiflorum) seems to be independent on mycorrhizal fungi under field conditions (Feldmann et al., 1993b); it is rarely found with mycorrhiza in nature and even under controlled greenhouse conditions a VA-mycorrhizal inoculation results in slight colonization.

While the importance of the mycorrhizal symbionts for the two plant species is quite well known, no information was yet collected about bacteria of their rhizosphere, their occurrence or potential mutual effects.

Based on these facts we decided to carry out experimental approaches in order to
- answer the question whether Hevea brasiliensis and Theobroma grandiflorum respond to an inoculation with already well known and proved RMO like Azospirillum brasiliense and Pseudomonas stutzeri which are involved in the natural N-cycle and can be found in Amazonian soils.
- test the effectivity of the inoculation with the two bacteria in presence of mycorrhizal fungi

The results on these two items were already publicated by Feldmann (1991).

The next step to be done in this project was to isolate and identificate rhizosphere bacteria from fresh roots of the two plant species in order to check their possible effect to a test plant (Petroselinum crispum) in a standardized steril test system in future exeriments.

Material and Methods

Undisturbed soil/root samples were collected from fields in Manaus, Brasil (done by Dr. H. Preisinger and Dipl.-Biol. P. Schmidt), sent in cooling boxes to Hamburg, and analyzed there.

The cultivation was carried out according to Dunger and Fiedler (1989), King (1954), Süßmuth et al. (1987); For the characterization standard microbiological tests like gram-staining, motility-test, Oxidase- and Katalase-tests, bio-Merieux-tests. The identification was computer aided (software "APILAB").

Results

Quantification and identification of rhizosphere bacteria

The evaluation of the RMO situation normally starts with a quantification of the bacerial microbes which are living in the rhizosphere of a host plant. That number of RMO is compared with the number of bacteria in the root-free soil next to the plant. The calculated value is the root/soil ratio and gives an impression in how far the amount of microbes is really influenced by the plant root. Table 2 shows the number of rhizosphere bacteria and the r/s-ratio of the rubber tree and the cupuacu tree.

In the rhizosphere of both plant species much more microbes are found than in the root-free soil. The rubber tree Hevea brasiliensis has even more bacteria in the rhizosphere than the cupuacu tree Theobroma grandiflorum.

Table 2: Number of rhizospere bacteria [n/g root dry weight] and root/soil ratio of bacteria of two tropical useful plants

	number of R-bacteria	Root/soil ratio
H. brasiliensis	4.8×10^4	24
Th. grandiflorum	2.1×10^3	6.3

Table 3: Identificated rhizosphere bacteria from roots of the two useful plants Theobroma grandiflorum and Hevea brasiliensis

	genus of RMO	potential species
H. brasiliensis	Aromonas	A. hydrophila
	Azomonas	A. agilis
	Flavobacterium	F. multivorum
	Pseudomonas	P. cepacia
Th. grandiflorum	Acinetobacter	A. mimawoffi
	Azomonas	A. agilis
	Flavobacterium	F. breve F. multivorum
	Pseudomonas	P. cepacia P. flava P. luteola P. mallei P. pseudomallei

The identification of the microbial community leads to an interesting result (Table 3): only four species of bacteria could be isolated from the rhizosphere of the rubber, while the bacterial community of cupuacu roots contained nine species.
On rubber tree roots only one specific species (Aromonas hydrophila) was identified which did not occurr on cupuacu roots.
The most frequent bacterial genus on the roots of the cupuacu tree was Pseudomonas (five of the nine bacterial species were identified as Pseudomonas).

Those descriptions of the occurrence of rhizosphere bacteria are only a first step to understand the role which RMO play for the plant. The next step is to learn how the potential abilities of an isolated bacterial strain could be. This can be tested in a standardized testing system like shown in the next chapter.
After such a pre-screening of the isolated bacterial strains selected bacteria can be multiplied and at last the useful plant they are isolated from can be inoculated with that strains to evaluate the effect to the useful plant itself.

Within this project it was only planned to isolate the RMO from the rhizosphere of the useful plants. Nevertheless we started already a preliminary study on the growth behaviour of a testing plant inoculated with bacterial strains isolated from rubber tree and cupuacu tree roots.

Preliminary investigations on the effect of rhizosphere bacteria in a standardized testing systems

In a standard system for the effectivity test of rhizosphere bacteria Petroselinum crispum as host plant was used.
Into a 250ml Erlenmeyer-vial 115g sand (1-3mm particle size) and 25ml nutrient solution (Murashige and Skoog, 1962) were filled and then sterilized by autoclavation. One surface sterilized and pregerminated seed of Petroselinum crispum was introduced into the vial. After fourteen days the seedlings were inoculated with a bacteria suspension containing 10^5 cells. The plants were grown in growth chambers with 10h/12h light with 85 E/cm^2 x sec, and a temperature of 20-22°C.

As shown in table 4 the testing plant Petroselinum crispum showed a positive growth response with one of the isolated rhizosphere bacteria. That bacterial species was of the genus Pseudomonas (P. luteola) and was isolated only from the rhizosphere of Theobroma grandiflorum. The inoculation with other bacteria did not influence or even decreased the growth of parsley.

Table 4: Growth response of Petroselinum crispum in a standardized testing system to the rhizospere bacteria collected from the roots of the two useful plants Theobroma grandiflorum and Hevea brasiliensis

genus of RMO	potential species	growth response
Acinetobacter	A. mimawoffi	o
Aromonas	A. hydrophila	o
Azomonas	A. agilis	o
Flavobacterium	F. breve	o
	F. multivorum	o
Pseudomonas	P. cepacia	o
	P. flava	o
	P. luteola	+
	P. mallei	o
	P. pseudomallei	o

Test plant: Petroselinum crispum; sterile standard conditions (see text); "o" no growth respnse, "+" positive growth response

Conclusion

Respecting the findings of Feldmann et al. (1993) that the cupuacu tree can be charaterized as only facultatively mycorrhizal with a tendency not to form mycorrhiza under natural conditions the studies on the interactions between bacterial RMO and the cupuacu tree are of high interest. The data described above show that the rhizospere of cupuacu influences the quantity and the quality of the bacterial RMO community in a significant way - even more than the rhizosphere of the rubber tree does, which is obligately mycorrhizal. Aditionally to that a growth promoting bacterial strain already could be isolated from the rhizosphere of cupuacu roots.

The questions which arise from these findings are: could it be that cupuacu depends on the presence of growth promoting bacteria while the presence of mycorrhizal fungi is not as important for that tree than for the rubber tree? Do our investigations therefor indicate two different modes of interactions between RMO and useful plants?
We hope that we can step forward in 1994 with the next step, the inoculum mass production of the isolated growth promoting bacterial strain and its inoculation to seedlings of Theobroma grandiflorum.

See also Appendix 4: Kubrom 1993; Abstract

4.2 Interactions between Rhizobia, mycorrhizal fungi and plant fertilization

Mycorrhizal fungi very often meliorate the nutritional status of the host plant. In contrast, strong fertilization - especially with phosphorus - influences the degree of colonization by mycorrhizal fungi negatively. Low concentrations of nitrogen in the soil guarantees a good nodulation of potential hosts (leguminosae) if compatible rhizobia are present.
But what happens if a plant like the here cultivated Schizolobium amazonicum forms intensive mycorrhizae (compare Feldmann et al., 1994a) but does not show any growth response? Do they need rhizobia? Is the nodulation influenced by the mycorrhization? Are the introduced mycorrhizal fungi not effective? Is the lack of effect due to changes in the fertilizer status?
In a first step to clarify such interactions between fertilization and different growth promoting soil microorganisms we planned an experiment with a testing plant which can be multiplied under sterile conditions very easily (Baptisia tinctoria) and therefore can be inoculated separately only with rhizobia and later together with mycorrhizal fungi under controlled fertilization conditions. This work will be done by Dipl.-Biol. M. Keller (not financed by the BMFT). The results should be transferred later in a second step to Schizolobium amazonicum, a useful plant cultivated in the current project.

5 Potentially antagonistic organisms: Collembola

Many results of different fields of work indicate that besides abiotic changes biotic factors of the soil can influence the interactions between mycorrhizal fungi and plants negatively. For example the inoculum production can be worse in presence of Collembola (Sreenivasa and Bagyaraj, 1989). There is some evidence that those insects act as antagonistic organisms, eating spores and hyphae and deminishing in that way the inoculum potential. In spite of such negative investigations as well such organisms can possibly help spreading fungal spores in a small extent.
To clarify the role of the very important group of Collembola we started in cooperation with Prof. Dr. Larink from the Technical University of Braunschweig a study about the feeding behaviour of those insects in the presence of VA-mycorrhiza. The student G. Meyer started to work on her Diplom-thesis in November 1993 (not financed by the BMFT). The methods and results which will be worked out in the next months probably will later be transferred to comparable experiments in Manaus.

Dicussion

In the first 20 months of the project "Recultivation..." the introduction of mycorrhizal symbionts was one of the most important innovations which characterizes the whole project. Selected fungi - most of them already tested in Amazonas before the project started - were included into the plant production system, first in nurseries and afterwards in the field.
The plant response to the mycorrhizal inoculation showed great advantages for mycorrhizal plants: better growth and health, better effectivity of nutrient uptake and lower loss rates than without inoculation of selected fungi. In the most of the cases only 30% of the recommended fertilizer dosis was sufficient to reach growth responses as high as in the 100% recommended dosis treatments or even higher.
Nevertheless the review of the results and the methodology of the mycorrhizal management carried out during these first phases of the project detects several practices which have to be changed in future to optimize the usefulness of the mycorrhizal fungi.
An important example in the plant production system is the production of root stocks of Hevea brasiliensis for later budding. The extraction of the seedlings after germination

from the substrate followed by the removal of all fine roots deminishes the possibility of mycorrhizal fungi to colonize the root system before planting into the field drasticly. If such a practice is avoided e.g. much better growth response is guaranteed (Feldmann, 1991). Here like in other cases (Citrus, Cocos, Pupunha), the time period between mycorrhizal inoculation, root forming and planting into the field was suboptimal.
Later - under field conditions - the plants are intensively fertilized directly in contact with the root system. As we know the mycorrhizal formation and the efficacy can be influenced negatively by high fertilizer dosis. We don't know presently, if the effectiveness of the symbiosis could be enhanced easily by changing the fertilizing modus during the planting of the hosts into the field.
Another very important example on the side of the fungal symbionts is the question whether to use mixed populations of different fungal isolates or pure inoculum when introducing them to the useful plants. As we noticed in several interactions there could be competitive interactions between the introduced and the indigenous fungi. It must be clarified if this behaviour exists between the isolates of selected fungi, too.

Summarizing all aspects of the use of mycorrhizal fungi in this project the recent results already indicate, that the inclusion of mycorrhizal fungi into the plant production system as installed here will significate an important economic success. The costs of the introduction and the value of the advantages caused by the use of mycorrhizal fungi is evaluated presently.
In the next two years mainly the ecological aspects of the introduction of the root symbionts will be studied. The first analysis of the great influence of the slashing and burning during the preparation phase of the plantations could significate that the survival of the introduced fungi could be higher than expected before. Possibly the introduced fungi can sustainingly establish themselves in the fields.

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Appendix 1

Feldmann, F., Gasparotto, L., Lieberei, R., Preisinger, H. (1994c): Utilization of abandoned areas in Amazonia by polycultures of perennial useful plants Proceedings of the International Symposium "Manejo e reabilitacao de areas degradadas e florestas secunda-rias na Amazonia 18.-22.04.1993, Santarem, Brasil (in press)

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Utilization of abandoned areas in Amazonia by polycultures of perennial useful plants

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Summary

Degraded fallow areas of primarily monocultural plantations will be transferred into a locally-adapted form of utilization under special consideration of soil microbiological factors (fungal and bacterial symbionts). In accordance with the heterogeneity of natural plant communities, polycultures of several perennial and annual ecologically adapted useful plants are installed. During the installation phase mycorrhizal fungi are introduced as important biological factors to optimize the ecological fitness of the plant material. After the implantation of the polyculture the spontaneous secondary vegetation is managed carefully to reach to a benefitial jointly growth of the secondary vegetation with the useful plants. In this type of naturally enriched polyculture special regard is paid to a careful use of pesticides and fertilizers in order to come to a plant production system with low input and sustaining medium output. Low input systems with a mixture of annual and perennial plants result in an ecologically and economically equilibrated situation for small scale producers.

In this contribution the organization of a multidisziplinary project between Brasilian and German institutions is demonstrated as well as the results of the installation phase of the project.

Several studies indicate, that principally a recultivation of abandoned areas is possible. The main problems lie in the fact that a recultivation has to be sustainable for a very long time period and therefor has necessarily to be profitable for small scale producers. That means that methods have to be developed which lower the input into a production system - especially during the critical installation phase - and ensures an output which meliorates the life standard of the producers without loosing the productivity of the fields already after a short time.

In the attempt reported here different factors are taken into account which are stabilizing biological controlling systems (e.g. for nutrient cyclization or epedimiolgy of diseases).

The managment practices include treatments for the improvement of biological factors of soils (Feldmann et al. 1989; Feldmann and Idczak, 1992; Feldmann et al., 1993a), e.g. the introduction of symbionts and the utilization of plants which are mycotroph and living in symbiosis with N-fixing bacteria (Feldmann et al. 1993b); beneath that a high number of plant species together with the useful plants is allowed to grow, and the use of pesticides is minimized.

In cooperation with the three large institutions in Manaus
CPAA, INPA and UNAMAZ/UA the following items will be carried out:

- Former plantation areas of the CPAA are recultivated with polyculture systems of different useful plants.
- Symbiontic fungi are multiplied and inoculum is prepared using locally adapted methods.
- In the initial phase of the project selected symbionts are used to optimize the plants' establishing phase, health and growth.
- Recultivation is accompanied by studies on the ecological and economical effect of natural secondary vegetation growing spontaneously in the polycultural system.
- a management concept for the transfer of the results into the common practice will be deduced from the results.

2. Theoretical basis for the project

Prior results demonstrated the importance especially of soil-microbiological factors, the adaptedness of the utilized plants and the heterogeneity of the vegetation for the stability of agroecosystems. These parameters are the basis for a successful recultivation of fallow lieing and degraded areas and their longterm use.

The plant production system demonstrated here therefore fulfills the following items:

- An adapted agroecosystem in the Amazon basin has to be a polyculture with the use of mainly perennial, indigenous trees.
- Degraded areas have only very few essential, symbiontic organisms (see Feldmann et al., elsewhere in this volume). In the initial phase of a recultivation effective symbionts, especially mycorrhizal fungi, have to be introduced to the plant production system.
- A high soil-microbiological stability and high diversity of effective, adapted soil microorganisms is supported by a high number of different host-species. That means that the inclusion of the natural secondary vegetation should have high importance for the stabilization of populations of soil-microorganisms and therefor for the introduced hosts - the useful plants -, too.
- The management of the plantation has to be carried out in a way that a high diversity of soil-microorganisms remains in the soil. That means a low input of pesticides and a controlled amount of fertilizers (normally much less than without mycorrhization of the plants) is recommended.
- A high diversity of useful plants/natural vegetation probably will enhance the disease tolerance of the whole system by changing the microclimate and giving the possibility to establish natural controlling systems, as long as the secondary vegetation does not contain host plants for pathogens or pests, which attack the crops.
- The selected useful plants have to be acceptable for the people of the Amazon region. The produced goods must have a commercial value.
- The products must be suitable for being transported.
- The installation of the plantation and the products must be profitable.
- Modifications of the management practice must be accepted by producers and must be practicable under local conditions.

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The plant production system demonstrated here therefore fulfills the following items:

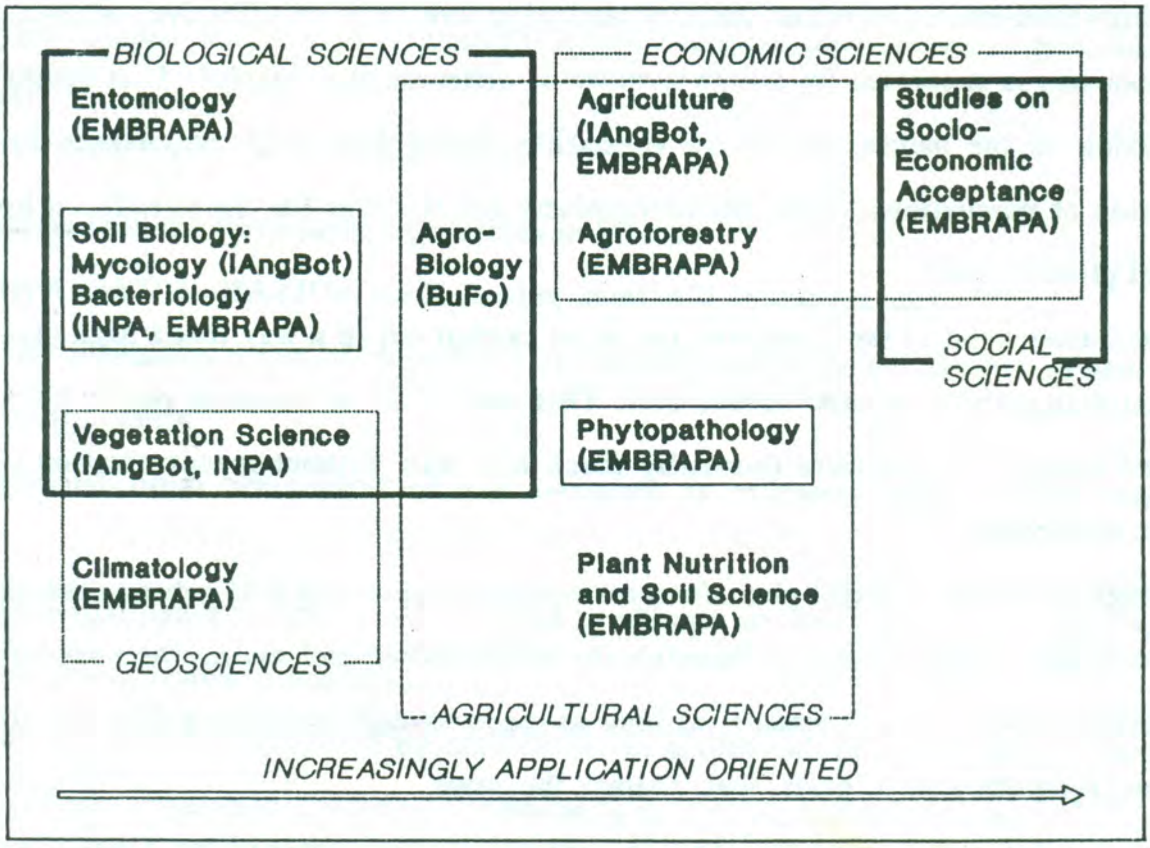
- An adapted agroecosystem in the Amazon basin has to be a polyculture with the use of mainly perennial, indigenous trees.
- Degraded areas have only very few essential, symbiontic organisms (see Feldmann et al., elsewhere in this volume). In the initial phase of a recultivation effective symbionts, especially mycorrhizal fungi, have to be introduced to the plant production system.
- A high soil-microbiological stability and high diversity of effective, adapted soil microorganisms is supported by a high number of different host-species. That means that the inclusion of the natural secondary vegetation should have high importance for the stabilization of populations of soil-microorganisms and therefor for the introduced hosts - the useful plants -, too.
- The management of the plantation has to be carried out in a way that a high diversity of soil-microorganisms remains in the soil. That means a low input of pesticides and a controlled amount of fertilizers (normally much less than without mycorrhization of the plants) is recommended.
- A high diversity of useful plants/natural vegetation probably will enhance the disease tolerance of the whole system by changing the microclimate and giving the possibility to establish natural controlling systems, as long as the secondary vegetation does not contain host plants for pathogens or pests, which attack the crops.
- The selected useful plants have to be acceptable for the people of the Amazon region. The produced goods must have a commercial value.
- The products must be suitable for being transported.
- The installation of the plantation and the products must be profitable.
- Modifications of the management practice must be accepted by producers and must be practicable under local conditions.

3. Organization of the project

The existing working group is composed of scientists from the CPAA, EMBRAPA, Manaus, Brasil, the Institute for Applied Botany of Hamburg University, FRG, the Federal Institute for Timber and Forestry in Hamburg, FRG, and the INPA, Manaus. It covers areas of several disciplines as shown in Fig. 1.

Basic knowledge has been or is being accumulated in the field of mycology, bacteriology and vegetation science; application-orientedness increases in the direction of the arrow. For this reason, the acceptance studies designed to find out whether farmers in the region are in fact willing to apply the tested cultivation systems in practice are positioned on the far right of Fig. 1

Figure 1: Scientific disciplines and institutions involved



IAngBot = Institut für Angewandte Botanik, Hamburg, FRG; BUFO = Bundesforschungsanstalt für Holz- und Forstwirtschaft, Hamburg, FRG; EMBRAPA (CPAA) = Empresa Brasileira de Pesquisa Agropecuaria da Amazonia (Centro de Pesquisa Agroflorestal da Amazonia), Manaus, Brasil; INPA = Instituto Nacional de Pesquisa da Amazonia, Manaus, Brasil

4. Description of the field trial

In the 19ha plantation, we intend to test the three following ways of stabilizing crops in different test variants:

- Inoculation of the plants with mycorrhizal spores
- Testing of different mixed cultivation systems
- Fertilization in different fertilizer regimes
- Experiments on management of the spontaneous vegetation in the crop systems to improve the competitive conditions for the planted crops.

Table 1: **List of planted species**

Common name	Scientific name	Plant family	Use
Seringueira	Hevea spp.	Euphorbiaceae	Rubber production, oil production from seeds
Cupuaçu	Theobroma grandiflorum	Sterculiaceae	Pulp (juice, ice, dessert), pods (chocolate)
Pupunha	Bactris gasipaes	Arecaceae	Fruit, palmito, fodder (leaves), food colourings (fruit flesh), weaving material
Castanha do Brasil	Bertholecia excelsia	Lecythidaceae	Brazil nuts, timber
Urucum	Bixa orellana	Bixaceae	Dyestuffs sunscreens
Côcos	Cocos nucifera	Arecaceae	Oil, copra, coconut milk, feeding stuffs (oil cake), weaving material, fibres, construction timber, particle board
Citrus	Citrus sinensis	Rutaceae	Fruit, oil, pectin
Paricá	Schizolobium amazonicum	Caesalpiniaceae	Timber, charcoal
Mogno	Swietenia macrophylla	Meliaceae	Timber
Andiroba	Carapa guianensis	Meliaceae	Timber, oil
Mamão	Carica papaya	Caricaceae	Fruit, papain, carpain, feeding stuffs
Mandioca	Manihot esculenta	Euphorbiaceae	Starch, vegetables from the leaves
Feijão	Vigna sinensis	Fabaceae	Green fodder, starch
Milho	Zea mays	Poaceae	Starch, edible oil, feeding stuffs
Puerária	Pueraria phaseoloides	Fabaceae	Cover crops

4.1 Planted crops and plantation systems

14 species of useful plants were planted in the experimental field (table 1).

Four different mixed cultivation systems (systems 1-4, see table 2) and four conventional monocultures (systems 6-9) are to be compared in the field trial. System 5 is land which was prepared in the same way as the other systems and then left to its own devices. Perennials, short-term crops for planting between the rows and cover plants are being used in the systems. The choice of crops was based largely on current marketing prospects.

Table 2: Useful plants grown in different plantation systems

	Plantation systems									
	mixed cultiv.				f	monocultures				
	1	2	3	4	5	6	7	8	9	
Seringueira	*		*	*		*				perennial useful plants
Cupuaçu	*	*	*				*			
Pupunha	*	*						*		
Castanha do Brasil		*								
Urucum		*								
Côcos			*							
Citrus			*						*	
Paricá			*	*						
Mogno				*						
Andiroba				*						
Mamão	*									short living useful plants
Mandioca		*	*							
Feijão			*							
Milho			*							
Puerária	*	*	*			*	*			cover crops
spontan. vegetation				*	*			*	*	

f = fallow (for comparisons)

System 1 is a comparatively intensive cultivation system with little space left between the rows. More space was left between roes in systems 2 and 3, which can be used for growing short-term crops in the first year. In practice, this would help farmers survive the first years after establishment of the plantation, during which the longer-lived species are not generating any income. System 4 is the most "extensive" of the test systems. The species planted produce timber. Secondary vegetation is tolerated between the trees. In systems 1-3 and in monocultures 6-8, on the other hand, cover plants have been sown (Pueraria phaseoloides). For the later transfer to practice probably not only one but an appropriate combination of different systems will be recommended.

4.2 Plantation systems and layout on the fields

The nine plantation systems described are being established in different test variants (table 3). Some of the young plants have been inoculated with mycorrhiza, the remainder have not. The fertilization variants include zero fertilizer, 30% and 100% of the recommended dose for the respective species.

Table 3: Plantation systems and test variants applied

n = 54	0 fertilizer		30% fertil.		100% fertil.		
	– myc.	+ myc.	– myc.	+ myc.	– myc.	+ myc.	
system 1			*	*	*	*	mixed
system 2			*	*	*	*	culti-
system 3			*	*	*	*	vation
system 4				*			
system 5	*						fallow
system 6					*		
system 7					*		mono-
system 8					*		culture
system 9					*		

- myc. = not inoculated with mycorrhizal fungi spores
+ myc. = inoculated with mycorrhizal spores

That gives a total of n=54 possible variants. In our experiment we implemented the 18 variants which promise to give the most meaningful comparisons.

In the field test the 18 variants are being laid out as blocks, with five complete blocks and repeats. The position of the variants within the blocks is completely randomized. The plots have an area of 48 x 32 m^2 each. The layout of the plots is determined by the elongated, irregular shape of the experimental area. A 100 x 100 m^2 patch of secondary forest was left standing at the edge of the area for comparative studies of the secondary vegetation.

The experimental area concerns terra firme lands on the EMBRAPA site, Km 28, Am 010. These areas were first cleared of primary forest about ten years ago, then used as rubber tree monocultures and and last left unattended. In August 1992, the approximately eight-year-old secondary forest was cleared and burnt in the traditional manner. Since April 1993 the plantation is established.

5. First results of the project's installation phase

5.1 Spontaneous vegetation four months after clearing

Before the secondary forest on the test area was cleared, a floristic study was carried out, which yielded 178 species, mainly trees. Four months after clearing - and after the area had been surveyed and divided into plots - growth form types of the spontaneous vegetation of all 90 plots of the trial were assessed quantitatively, i.e. on the basis of their respective area coverage. The patterns are the result of the former use of the sites and of pedological differences between sites within the experimental area.

A preliminary analysis of the data reveals heterogenous vegetation patterns within the plots (on a m^2 scale), but clearly distinguishable patterns in a north-south direction (from block A to block E). The following growth forms show dominance in the blocks of the experimental area as shown in table 4.

A more detailed analysis of the data is yet to come. So far the patterns are interpreted as patterns of different intensity of use,

Table 4: **Growth form structure of the spontaneous vegetation in the different blocks 4 months after clearing**

Growth forms		dominant in block(s):
Trees		A, B
Shrubs		nowhere dominant
Herbs	Tussock grasses	B, D, E
	Stolon grasses	nowhere dominant
	upright growing dic. herbs	D
	creeping, dicotyl. herbs	C, D
	Ferns (bracken)	E

dic./dicotyl. = dicotyledones

or also differences in intensity and frequency of disturbance. Although these differences will in part be cancelled out by subsequent management measures, the vegetation differences observed are important as they represent the starting conditions of the experiment and must be included as site differences in the final trial evaluation.

5.2 Control of wild vegetation in the plantation

The spontaneous vegetation which regenerates or colonizes the space between the plantation crops can, on one hand, constitute competition for the crops (light, nutrients, space) and must be suppressed in this case. On the other hand, the wild vegetation can be an important store of nutrients, which become available to the crops after dieback and mineralization of the biomass. As well a high diversity of the secondary vegetation probably will mean an equilibration of ecological controlling systems, e.g. occurrence of diverse communities of symbionts or other benefitial microbes. Whether these two opposed processes can be optimized in favour of the crops by appropriate control of the wild vegetation, is a question which has to be examined.

Basecally there are three ways of controlling growth of wild vegetation (fig. 2):

- the secondary vegetation is allowed to regenerate, but is occasionally cleared from the space immediately around the crop plants. In this case mainly trees, i.e. long-lived growth

forms, would benefit. The species spectrum would be compressed due to the occasional disturbance.

- the cultivation area is kept free of taller growth forms, i.e. the regeneration of secondary forest species is frequently disturbed. In this case the long-lived herbs and grasses would benefit.

- herb species with creeping growth forms are sown, e.g. Pueraria. This would lead to a dense undergrowth of one or a very few species.

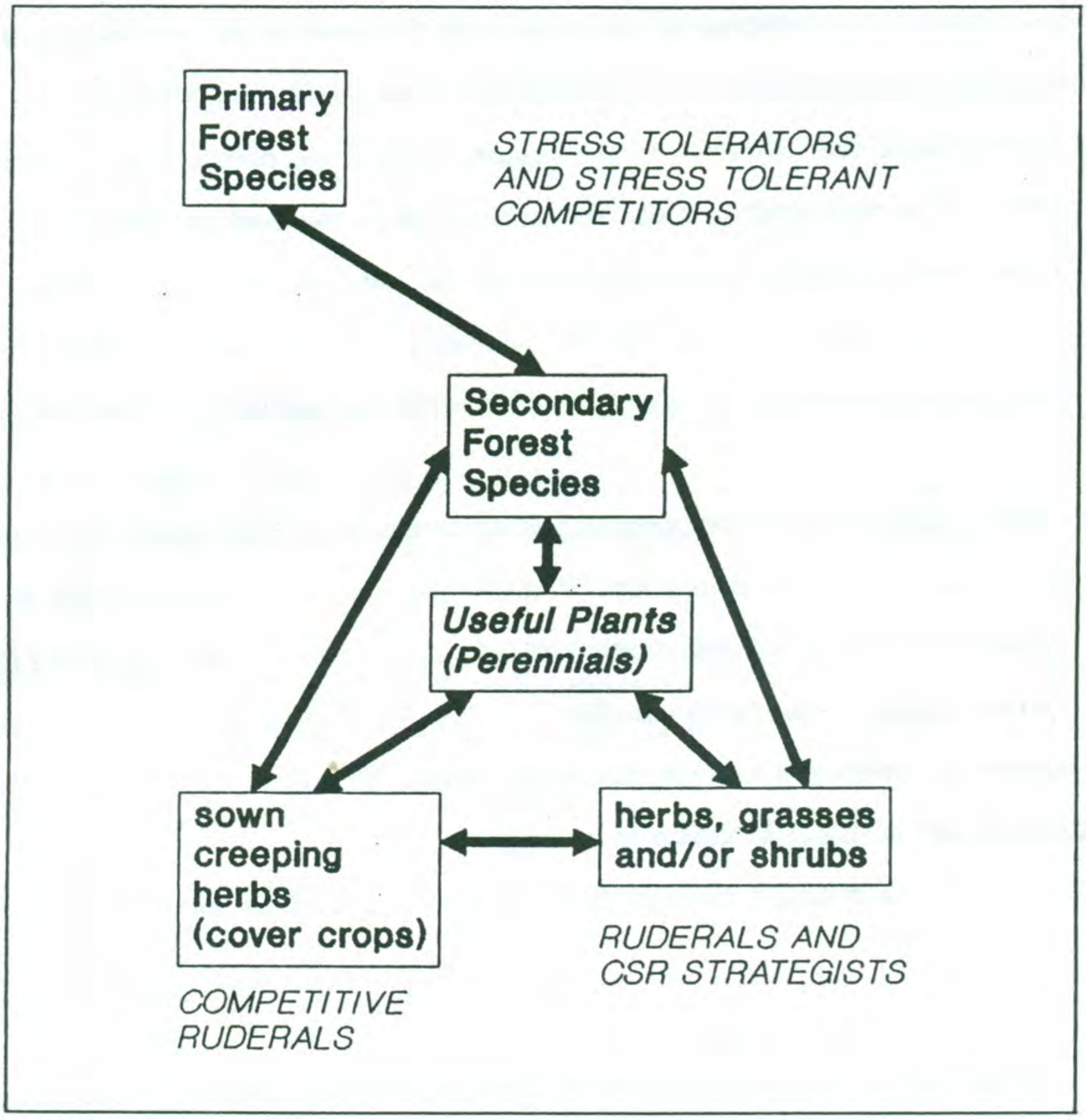
The three different ways of treating the undergrowth each favour different eco-morphological plant types according to Grime (1979, 1988):

- sowing favours fast-growing types with a high nutrient requirement (competitive ruderals)

- frequent cutting and hoeing favours short-lived herbaceous species and species which can regenerate quickly from the buds at the soil surface (ruderals and CSR strategy types),

- minimum management favours regeneration of part of the species spectrum of the secondary forest.

Figure 2: **Three ways of controlling wild vegetation in the plantation**



The arrows indicate different competitive situations due to the management of the planting systems. CSR strategists according to Grime (1979, 1988)

In the field experiment cover plants have been sown (see above) in some of the test variants, because of the positive experience on the farming site that exists with this method; in other variants secondary vegetation will be tested as cover plants.

5.3 Occurrence of mycorrhizal fungus spores before and after burning

The highly important symbionts of the most of useful plants in tropical regions are severly influenced by the management practices in Amazonian plantations (Feldmann and Lieberei, 1992). To estimate the influence of the burning before the plantations' establishment 40 soil samples were surveyed to count the number of spores and to classify the occurring spore types before burning. Immediately after the burning new samples were taken and evaluated. At the same time a further estimation of the most probable number of propagules in the plantation soil was done (following the method of Feldmann and Idczak, 1992).

It was found that all over the plantations an average of 658 spores per cm^3 soil of vesicular-arbuscular mycorrhizal fungi (VAMF) occurred, but only one third of them was alive. An infection and rapid colonization of the root systems of catching plants (Zea mays, Petroselinum crispum) was easily possible.

A complete identification of the occurring fungi was not yet possible. But a first classification of the spores is shown in table 5.

From each spore type single spore isolates are now prepared for an exact identification or description.

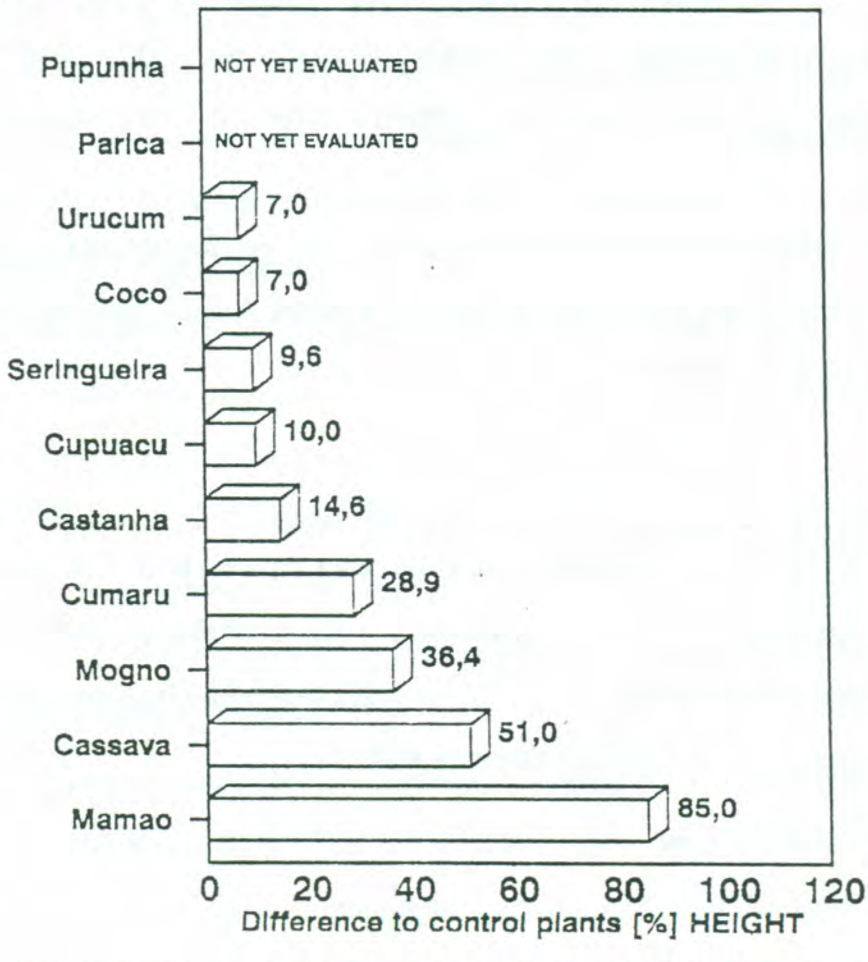
Directly after burning no infection and no living spore was counted in soil sampled from the above 5 cm of the soil surface. Even six months after burning preliminary examinations (one MPN test with 5 dilutions and 5 replications with a mixed soil sample from all over the plantation) did not show any mycorrhization in the testing plants (Zea mays). This strong impact of the fire with regard to the survival of the mycorrhizal fungi was not expected, but shows the dramatic changes which come along with the burning of the fields. Further periodical tests will show how long it will take until the infection potential of mycorrhizal fungi arises again in the test fields.

Table 5: **Percentage of VAMF spore numbers in soil samples from the plantations before burning and distribution on spore type classes**

spore type	[%] of total n	$percentage_{min}$	$percentage_{max}$
Glomus A	41,2 ± 9,3	28	62
Glomus B	37,2 ± 7,5	24	49
Scutellospora A	9,9 ± 7,1	0	23
Scutellospora B	3,0 ± 3,2	0	11
Acaulospora	3,6 ± 3,7	0	12
not ident./others	5,5 ± 3,1	0	11

The total spore number was in average 658 ± 176 spores / 50cm3 soil in n=40 samples. Only 27% of these spores were alive, but the infection potential of the soil was high.

Figure 3: **Growth response of some useful plant species to inoculation with mycorrhizal fungi in nurseries**



The evaluation of the height was made ten weeks after inoculation with mycorrhizal fungi. The utilized mycorrhizal fungi were Glomus etunicatum, Glomus manihotis and Glomus intraradices.

5.4 Use of mycorrhizal inoculum in the plant production

As described above plants of the half of the test variants were inoculated with mycorrhizal fungi. How the fungi were selected and how the inoculum was produced is described elsewhere in this volume.

All yet evaluated inoculated plant species showed a much better growth than plants without inoculation (fig. 3).

6. Conclusions

The first results show a growth response of the useful plants before being outplanted into the fields. Aditionally the preparation of the fields with the common practice of burning resulted in a sever deficacy of fungal symbionts in the soil. It is expected that the better growth of the useful plants in the nurseries due to mycorrhizal fungi will result in a better initial growth in the field, too. Possibly this advantage will decide on survival or fade of the plants under the unfavourable conditions of degraded stands. While the introduction and utilization of mycorrhizal fungi is very cheap and easily made this would demonstrate the first step of a new plant production system which finally will combine a low input with a sustainable output.

The other steps following from now on in the growing and producing phase of the systems as well as the concluded final polycultural system with its special management practices will be published as soon as possible.

7. Acknowledgements

We thank our whole group of Brasilian and German co-workers for their extremely motivated work during the preparation and installation phase of this project.

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Utilizacao das areas abandonadas na Amazonia por polyculturas

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INTRODUCAO

Ate hoje uma producao agricola na Amazonia normalmente e possivel somente com aplicacoes muito altas dos adubos e pesticidas (high input-agriculture). Causas pela necessidade do "high input" sao as especialidades do solo e do meio ambiente tropico e o uso das monoculturas. Nas moncuituras um desequilibrio total dos fatores ecologicos existe que causa no minimo uma reducao do retorno, muitas vezes o abandono das plantacoes.

Num projeto interdiszipiinario pesquisadores da EMBRAPA, do INPA, da UNAMAZ/UFA, Manaus-AM, e do Instituto da Botanica Applicada, Hamburg, Alemanha, desenvolveram um sistema dos cultivos que inclue diversos aspectos novos: uma polycultura com no minimo quadro plantas perenes nativeis da Amazonia foi plantada, fungos micorrizicos foram usadas na fase da implantacao e uma modificacao do manejo das plantacoes sera desenvolvido que respeita as necessidades dos microrganismos do solo (por exemplo menos adubos, menos pesticidas, mais plantas secundarias).

O PROBLEMA DAS AREAS ABANDONADAS E UM PROBLEMA BIOLOGICO A RESOLUCAO E BIOLOGICA TAMBEM

NO PROJETO OS FATORES ECOLOGICOS "VEGETACAO SECUNDARIA" E "FUNGOS MICORRIZICOS" TEM POSICAO DE CHAVE

Numa area usada desenvolve-se uma vegetacao secundaria alta

Mais importante no solo sao os simbiontes (fungos micorrizicos)

NO PROJETO O CRESCIMENTO E O DESENVOLVIMENTO DOS CULTIVOS NUMA MONOCULTURA E NA POLYCULTURA SERA COMPERADO

Sistemas da Monocultura:	Sistemas da Polycultura:
1. Seringueira	1. Seringueira, Mamao, Pupunha, Cupuacu
2. Pupunha	2. Castanha d.B., Urucum, Cupuacu, Pupunha, Mandioca
3. Cupuacu	3. Seringueira, Cupuacu, Parica, Coco, Citrus, Mandioca, Milho, Cowpea
4. Citrus	4. Seringueira, Mogno, Andiroba, Parica

A UTILIZACAO DOS FUNGOS MICORRHIZICOS E FEITO NO VIVEIRO PELA MISTURA DO INOCULO COM O SUBSTRATO E NO CAMPO PELA "NURSE PLANTS"

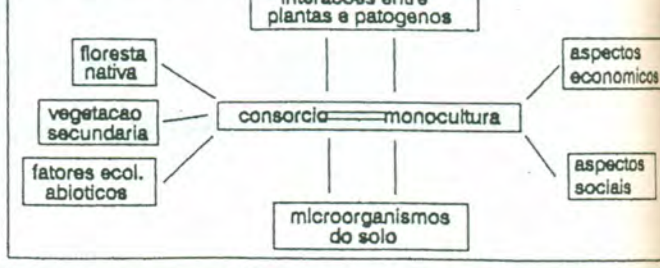
O INOCULO (AQUI JUNTO COM ARGILA EXPANDIDA) E MISTURADO COM O SUBSTRATO

NO CAMPO OS SIMBIONTES SAO TRANSFER[IDOS] POR "NURSE PLANTS" (MILHO; MAMAO E OUT[ROS])

Neste projeto piloto primeiro a phase initial de uma recultivacao das areas abandonadas e estudado. Esta phase e mais importante:

- ja no inicio todo manejo e todas as plantas selecionadas tem que guarantir um input baixo do produtor
- Somente um retorno rapido ja no primeiro ano pode ser uma base economica para o produtor e familia dele
- O efeito dos fungos micorrizicos e mais importante na phase initial; depois os fungos introdizidos provavelmente sao substituidos por fungos endemicos

ALEM OS ASPECTOS AGRICULARIOS PESQUISA DE BASE NAS DIVERSAS AREAS DA ECOLOGIA E SOCIO_ECONOMIA SAO FEITOS NESTE PROJETO:



Appendix 2

Feldmann, F., Idczak, E., Nunes, C.D.M. (1994c): Agricultural systems in Amazonia depend on the management of mycorrhizal fungi
Proceedings of the International Symposium "Manejo e reabilitacao de areas degradadas e florestas secunda-rias na Amazonia 18.-22.04.1993, Santarem, Brasil (in press)

Feldmann, F., Müller, I., Idczak, E., Lima, P., Nunes, J. (1993c): Sistemas de cultivos na Amazonia dependem do manejo dos fungos endomicorrizicos
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Agricultural systems in Amazonia depend on the management of mycorrhizal fungi

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Summary

A large quantity of tropical useful plants are dependend on mycorrhizal fungi. Without the fungal symbionts they show growth depression and lower tolerance to biotic and abiotic stresses. In plant production systems normally a deficit of symbiosis is created by the common management practices. In tropical regions with the system of shifting cultivation the fallow over some years was thought to have a positively regulating effect to the mycorrhizal situation. In this contribution it is demonstrated, that over three, respectively eight years of fallow there is an increase of the inoculum potential in the soils but the effectivity of the fungal populations remains very low in comparison to the populations from natural sites. The necessity to manage the mycorrhizal fungi in situ in the field is discussed.

Resumo

Titulo: Sistemas agricolas na Amazonia dependem do manejo de fungos micorrizicos

A maioria das plantas tropicais, de valor economico dependem de fungos micorrizicos. Na ausencia dos fungos simbiontes, as plantas apresentam baixo crescimento e baixa tolerancia aos "stresses" bioticos e abioticos. As plantas dos sistemas de producao normalmente apresentam um deficit de simbiose devido as praticas comuns de manejo. Nas regioes tropicais com os sistemas de cultivo itinerario, admitia-se que o pousio das areas teria um efeito regulado positivo na populacao de fungos micorrizicos. Neste trabalho, demenstia-se que mais os tres, ou

seja oito anos ha um aumento do potencial de inoculo no solo, mas a efetividade das populacoes fungicos permanece muito baixa em comparacao com as populacoes existentes nos sitios nativos. E discutida a necessidade do manejo dos fungos micorrizicos in situ no campo.

1. Introduction

The most of the tropical useful plants are facultatively or even obligatorily dependent on vesicular-arbuscular mycorrhizal fungi (VAMF) (Janos, 1987). Plants which are dependent on mycorrhizae under certain conditions show suboptimal growth and a higher susceptibility to stresses if a mycorrhization is lacking. In plant production systems normally a deficit of mycorrhiza exists: the substrate in greenhouses and in some nurseries is sterilized before use, and in the field the implantation of monocultures and the utilization of large quantities of pestizides deminishes the inoculum potential of VAMF drastically (Feldmann and Lieberei, 1992).

In several tropical regions, where shifting cultivation is still very common, the method of field preparation - normally slashing and burning - was discussed to be a very important impact for the mycorrhizal situation of the later grown useful plants on these stands (Feldmann and Lieberei, 1992).

If the preparation of an agricultural area by burning destroys the propagules of vesicular-arbuscular mycorrhizal fungi (VAMF) in the upper soil layers in the Amazon region was not yet known. Could it be that the burning of fields before installation of a plantation leads to a mycorrhizal situation that implicates an introduction of mycorrhizal fungi into the plant production system? Or could it be that a fallow of several years meliorates the situation at burned sites?

In order to step forward answering this question our group analysed the mycorrhizal situation in plantations directly after burning and after 3 years of fallow and in comparison to these stands in working plantations and natural sites.

2. Material and Methods

The natural vegetation of a terra firme stand in the near of Manaus (Km 28, AM 010) was cleared by fire to implant a rubber tree monoculture plantation there. After seven years this plantation was abandoned. The fallow area was located in direct contact with primary forst.

Three years after the abandonation the first survey of the mycorrhizal situation was made on the fallow area.

Data were collected about the degree of colonization and the Most Probable Number of VAMF Propagules in the soil.

The degree of colonization is the percentage of colonized roots which a root sample of 100 root pieces of 1cm length shows (Slide method, Giovannetti and Mosse, 1980).

The colonization of the roots was determined after they had been bleached and stained with lactophenol-cotton-blue (Philipps and Hayman, 1970).

The MPN (Most Probable Number, Porter, 1979) of propagules in a soil sample was carried out according to the description by Feldmann and Idczak (1992). Zea mays was used as the host plant. Five repetitions were carried out for each sample. The number of spores were counted after a wet sieving process (Daniels and Skipper, 1984).

Thirty samples of fine roots were taken from the surface and from the mineral soil from each surveyed stand of the rubber tree. Only samples of undoubtedly identified rubber tree roots were taken (tested by rinsing the root system). The root samples were combined and mixed. A sub-sample of 3 x 100 root pieces was taken from this collective sample and tested as described above.

The results were compared with nearby located natural stands of rubber trees in native rain forests.

After three years of fallow an effectivity test was made to compare the effect of not identified mycorrhizal fungus populations of the fallow area, monocultural areas, and natural sites. For this experiment the soil of the different sites was first tested by the MPN method. Than identical numbers of propagules were mixed with sterilized substrate and the effect on the growth and development of the mycorrhizal plants compared with non-mycorrhizal plants. The effectivity test was made with two plant species, with an annual graminae (Zea mays) and with seedlings of a perennial tree (Hevea brasiliensis, rubber tree).

After eight years of fallow the same area was slashed and burned to prepare it for the installation of a new plantation (see Feldmann et al. elsewhere in this volume). Directly before, immediately after the burning, and six months later soil samples were taken and the survival of the spores tested by bio-essay with Zea mays and Petroselinum crispum, the MTT-method (An and Hendrix, 1987) or by MPN-estimation. The MTT-method is a vital stain with 3-(4,5-Dimethylthiazol-2-yl)-2,5-Diphenyl-2H-Tetrazoliumbromid.

3. Results

After eight years of fallow a dense secondary vegetation desenvolved in the formerly monocultural plantation. The secondary vegetation contained 178 plant species (see Feldmann et al, elsewhere in this volume) and only the occurrence of the rubber tree remembered in the former use of the area. Together with the high number of plant species a high number of spores of vesicular-arbuscular mycorrhizal fungi occurred on the area (table 1). While nearly one third of these spores were alive this meant a quiet good inoculum potential in the soil.

The slashing and burning of the secondary vegetation led to a sterilization of the soil (table 1). Still spores were found, but all of them were dead (determined with the MTT-test). A MPN-test with five repetitions showed no colonization at all. Even six months after burning a MPN-test did not show active mycorrhizal fungi.

Table 1: Influence of slashing and burning to the inoculum potential of mycorrhizal fungi in the soil

	Spores/ 50cm3 soil	living spores	infectivity
before burning	658±157	27%	yes
directly after burning	539±135	0	no
six months after burning	412±112	/	no

Soil samples were taken in the upper soil layers (0-10cm depth). The spore number was counted after wet sieving, the percentage of living spores ("alive") was quantified with the MTT-test (An and Hendrix, 1987), the infectivity was tested by bioessay with Zea mays or Petroselinum crispum. (/) means "not determined".

The presented data show a dramatic impact of the burning to the VAM fungal association in the soils of implanted plantations. This impact sustains over more than six months, possibly more. Finally a regeneration of burned sites occurs: an investigation of 16 monocultural rubber tree plantations demonstrates, hat in every area one can find mycorrhizal spores. This was true in plantations of different age, in very young, 3 years old plantations, too. For example in rubber tree clone gardens (3 years old) there had been counted several living spores which were infective to testing plants. But even after 12 years the mycorrhizal situation in monocultural areas does not reach the conditions of natural sites. Only if monocultures were abandoned and lay fallow the number of spores, the root colonization and the MPN regenerated nearly to "natural" conditions. In table 2 results are shown of the analysis of undefined mixed populations of VAM fungi in still working monocultural plantations, in fallow lying plantations and - as a test standard - in near natural sites of the tropical rain forest. All sites - plantations and natural locations - were stands of the rubber tree. The spore numbers were counted and the Most Probable Number of

propagules in the soil was measured in each sample. Aditional to these measures root samples of the rubber tree from each stand were taken.

Table 2: Mycorrhizal situation of rubber tree stands

	Monocultural plantations n = 16	fallow areas n = 5	natural sites n = 11
Root coloni-zation[%]	30,4 ± 6,3	63,4 ± 9,5	72,2 ±10,8
Spore number/ cm^3 [n]	4,3 ± 2,1	15,6 ± 2,3	14,4 ± 5,9
Most Probable Number [n]	3,5 ± 1,4	12,5 ± 2,1	14,1 ± 3,2

The 16 monocultures of the rubber tree were of different age (3-12 years), the fallow areas were formerly used as monocultures and remained fallow lieing for three years.

In areas which were used as monocultures of the rubber tree the value for spore number and root colonization remains very low. Respecting the manyfold positiv effects of mycorrhizal fungi for the plant these circumstances can indicate a severe deficacy of symbiosis (compare Feldmann and Lieberei, 1992). In monocultural areas, which were let to lie fallow the number of infective propagules or spores were found to be as high as at natural stands of the rubber tree already three years after abandonation. But does this quantitative regeneration mean a qualitative melioration of the mycorrhizal situation, too?

To estimate the importance of mycorrhizal fungi for useful plants we selected two of them, the Graminae Zea mays and the Euphorbiacea Hevea brasiliensis for an effectivety test with VAM fungal populations.

Substrate from the testing areas of known infectivity was mixed with sterilized soil to reach an equal MPN in the planting substrate. Every treatment had its own control with sterilized substrate from the proprior stand. In table 3 the results of the effectivity test are shown.

The surprising result was, that in spite of a quantitative regeneration the populations in monocultures of the rubber tree as well as those from fallow areas were of low effectivity for the two crops in relation to mycorrhizal populations from native rainforest stands. The low effectivity was true especially for the rubber tree.

These data demonstrate that with the indigenous VAMF of rubber tree monocultures probably only suboptimal growth and a higher susceptibility to stresses of the crops can be expected in a field without a management of the symbiotic fungi. The data are urging upon the necessity to introduce management practices which allow the establishment of effective VAM fungi in this plant production system.

Table 3: Effectivity of undefined VAM fungal populations on the growth of Hevea brasiliensis and Zea mays

	VAMF of monocultural plantations		VAMF of fallow areas		VAMF of natural sites	
Testing plants	Zea	Hevea	Zea	Hevea	Zea	Hevea
Initial MPN [n/cm^3]	3	3	3	3	3	3
Root coloni-zation [%]	81	68	75	68	78	67
VAM growth response	1,22	1,03	1,35	1,05	1,72	1,41

The growth response is calculated by dividing the value for dry weight of mycorrhizal plants by the value of non-mycorrhizal plants. That means a positiv growth response due to mycorrhizal fungi if the quotient is above 1 and a growth depression if it is below 1. The plants were harvested three month (Zea) respectively six month (Hevea) after inoculation. n=50 (Zea) respectively 30 (Hevea) plants per treatment.

The most obvious method to meliorate the VAM fungal situation is to inoculate the crops with selected VAM fungi. Normally the VAM fungi are introduced into production systems whithout indigenous mycorrhizal fungi, e.g. into sterilized substrate. A more problematical approach it is, to add multiplied VAM fungi to non-sterilized soil. Our results (table 4) show that selected introduced mycorrhizal fungi are able to compete successfully with indigenous VAM fungi even under nursery (rubber tree) or field conditions (corn) in Amazonia.

While very few propagules of indigenous fungi (from fallow stands) can lead to a colonization of the root system of the two testing plant species even a better mycorrhization occurs when VAM fungi are introduced. Together with a better mycorrhization a better growth response in the mycorrhizal plants exists due to the changed degree of colonization or to qualitatively changed specific interactions between the symbionts.

Table 4: Effect of introduced VAM fungi competing with indigenous VAM fungi on the growth of rubber tree and corn

	Indigenous VAM fungi		Introduced Gl. etunicatum		Introduced Gl. manihotis	
Testing plants	Zea	Hevea	Zea	Hevea	Zea	Hevea
Initial/Inoculated MPN [n/plant]	4	4	30	30	30	/
Root colonization [%]	63	24	76	45	91	/
VAM growth response	1,00	1,00	1,61	1,39	1,71	/

The growth response is calculated by dividing the value for dry weight of mycorrhizal plants by the value of non-mycorrhizal plants. That means a positiv growth response due to mycorrhizal fungi if the quotient is above 1 and a growth depression if it is below 1. The plants were harvested three month (Zea) respectively six month (Hevea) after inoculation. n=50 (Zea) respectively 30 (Hevea) plants per treatment.

For the practical use of mycorrhizae in plant production systems there are two main possibilities for the introduction of mycorrhizal fungi: mycorrhizal inoculum can be mixed with the substrate of useful plants in nurseries of perennial plants or inoculum can be brought out together with the seeds of annual plants directly in the field. The latter method gives a third possibility; the annual plants, which are inoculated in this way, can function as "nurse plants", i.e. multiplicate the inoculum in situ in the field and transfer the propagules with their own root system to the roots of already planted perennial plants in the field (see also Feldmann et al., elsewhere in this volume).

An utilization of VAM fungi will only be accepted by producers, if the effect is decisive, long lasting, and profitable. Because of the deficacy of symbiosis in plant production systems normally the introduction of VAMF leads to economically interesting changes. But how long does the effect occur? This will be shown here in an example of the plant production system of the rubber tree (compare Lieberei et al., 1989).

Since nearly 100 years the rubber tree plantations in Amazonia are destroyed by a severe foliar disease, the Rubber Tree Leaf Blight, caused by the Ascomycete Microcyclus ulei. The introduction of mycorrhizal fungi into the plant production system of rubber tree plants (nursery use) can lead to a biological control of the foliar disease by the root symbionts (Feldmann et al., 1989). Mycorrhizal plants which are infected with the leaf pathogen show smaller lesions with drastically reduced sporulation of the pathogen. This effect was measured at four times after inoculation with the mycorrhizal fungus Glomus etunicatum. Everytime the same plants of three different rubber tree clones were used for the test. All plants which were inoculated with Gl. etunicatum were controlled to be mycorrhizal during the whole test. The results are demonstrated in table 5.

The interrelationship between the rubber tree, the leaf pathogen and the root symbionts is very clone specific. In the highly susceptible clone RRIM 600 the dramatic increase of the leaf resistance lasts more than 16 months. This effect decides on the survival of the plants with higher resistance. The more resistent clone Fx 4098

showed a resistance reaction which was strongly influenced by mycorrhization, too. But the effect disappeared 12 months after inoculation with mycorrhizal fungi.
The clone specifity of the mycorrhizal effect can also lead to the contrary effect in the early colonization phase: on leaves of plants of the clone Fx 3925, the most resistant of the tested three clones, primarily a slightly higher susceptibility to Microcyclus ulei occurred, but finally turned to a long lasting slight increase of resistance.

Table 5: Stability of the resistance enhancement in mycorrhizal rubber tree plants: reduction of the pathogen's sporulation (difference to control plants [%])

	4 months after VAM-inoculation	8 months after VAM-inoculation	12 months after VAM-inoculation	16 months after VAM-inoculation
clone FX 3925	-20	18	22	27
root colonization	27	27	30	32
clone FX 4098	76	60	76	0
root colonization	25	42	37	30
clone RRIM 600	78	80	55	75
root colonization	41	47	39	41

The example of the rubber tree demonstrates that the introduction of mycorrhizal fungi into the plant production system is very senseful and gives long lasting effects which can be of economical interest. This is true especially if the costs of the inoculum production are compared with the benefits of the VAM fungi. A detailed study on this subject will be publicated soon.

4. Discussion

In Amazonas the natural vegetation is normally cleared by fire to make place for plantations. The fire kills most of the host plants of mycorrhizal fungi in the burned areas and destroys the root layer growing on the soil surface. Therefore, a direct effect on the fungal populations is caused (Dhillion et al., 1987). Only after a rather long period of time, the burned areas re-attain infection potentials which they had before the fire. Wicklow-Howard (1989) noticed a period of 3-5 years necessary to re-establish the original infection rate caused by mycorrhizal fungi to host plants tested from the burned stands in Idaho (USA). The results presented in this research show that the infectivity of the soils due to mycorrhizal fungi reaches after 3 years of fallow the same value which natural stands of rubber trees have.

The re-colonization of destroyed soil layers by mycorrhizal fungi may be effected by inoculum spread caused by wind, water, and animals (Rabatin et al., 1987). Which species of mycorrhizal fungi colonize depends on the environmental conditions as well as on the plant species which are planted into the soil (Bevege and Bowen, 1975). In addition to negative influences of the fire clearance and the monoculture of a useful plant, several management practices utilized in the rubber tree cultivation affected the mycorrhizal potential of plantation soils (Feldmann and Lieberei, 1992).

If the plantation is a monoculture, the mycorrhizal community will generally be species-poor and the mycorrhizal populations are not much differentiated (Toro and Herrera, 1987). The diversification of host plants in a monoculture by means of growing some soil-covering plants improves the situation of mycorrhizae in plantations, however, this management practice alone is not sufficient to create natural growing conditions for rubber trees as shown in the results of our research on the occurrence of different soil-covering plants in rubber trees.

The comparison between the occurrence of mycorrhiza in rubber tree plantations and in their natural stands as well as the study of the effects which different management practices have on mycorrhizal colonization show a deficiency of mycorrhizal symbiosis in plantations. Taking the potential influences of mycorrhiza into consideration, this deficiency of symbiosis may probably lead to malnutrition, insufficient growth, and high susceptibility of rubber trees in plantations. A comparison between the mycorrhizal characteristics in rubber trees cultivated in plantations and those growing in their natural stands as well as their probable influences confirms this hypothesis. The data demonstrated here indicate that a management of the VAM fungal populations in the production systems of Amazonia is needed to optimize the possibility to include the benefits of the symbiosis between the crop and the mycorrhizal fungi.

While the re-establishment of growth stimulating mycorrhizal fungi takes place too slowly it seems to be necessary to inoculate the degenerated areas with selected, effective mycorrhizal fungi.

The use of mycorrhizal fungi in nurseries is unproblematic as shown in the cultivation of rubber trees. The inoculum of mycorrhiza can be mixed with the substrate at the time the rubber trees are planted or re-planted (Feldmann et al., elsewhere in this volume).

The introduction of mycorrhizae into old plantations, where the existence of mycorrhizae is insufficient in number or lacking, is, however, quite different. Inoculations can be carried out there - after introducing the management practices favourable to mycorrhiza - by means of the so-called "nurse plant", e.g. annual, useful plants which assist in an in situ-multiplication of mycorrhizal inoculum.

In all monocultures probably a change of the management practices and their adjustments is necessary to make it more favourable for the mycorrhizal fungi. The mycorrhiza must be included into plant protection concepts. For the rubber tree (see also Lieberei et al., 1989) that means that practices such as reducing the fungicides as well as lessening fertilization or dispensing of herbicides to destroy soil-covering plants near the trees has to be carried out. The most essential change may be the introduction of an intensive polyculture system in order to diversify the host plants for the mycorrhizal fungi. Several tropical useful plants, shown as suitable host plants for mycorrhizae, could be planted in such polycultures, e.g. Coffea arabica and

Citrus sinensis (Caldeira et al., 1983), mango (Cortes et al., 1984), Manihot esculenta (Powell, 1984), banana (Umesh et al, 1988), Bactrys gassipaes, Theobroma grandiflorum, Theobroma cacao, Carica papaya, Passiflora edulis, Bertholletia excelsa, Bixa orellana, Schizolobium amazonicum, Swietenia macrophylla, Cocos nucifera, Zea mays, Vigna uniculata and others (Feldmann et al., elsewhere in this volume).

With the cultivation of numerous different useful plants in a former monocultural plantation, the most important condition is provided keeping the survival of diverse and effective mycorrhiza populations. The adaption of management practices favourable to the root symbionts means a first step to the ecologically balanced, stabilized culture system of perennial useful plants. It is expected that this system would lead to an improvement of the environment and a more productive agriculture on nutrient deficient or otherwise problematical soils.

5. Acknowledgements

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SISTEMAS DE CULTIVOS NA AMAZONIA DEPENDEM DO MANEJO DOS FUNGOS ENDOMICORRIZICOS

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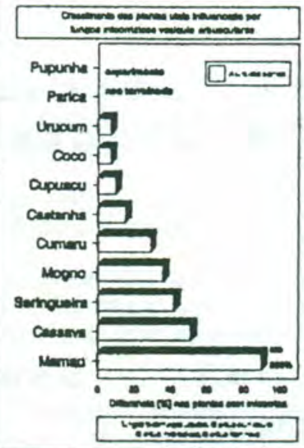
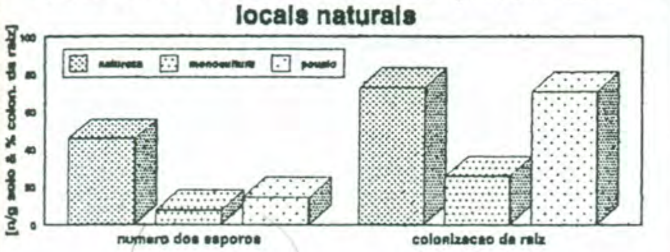
RESUMO

Multas plantas uteis tropicas dependem da presencia dos fungos endomicorrizicos para o meilor crescimento e saude delas. Na casa de vegetacao observamos uma aumenta da biomassa ate 200% por causa da micorizacao por exemplo no mamaoeiro. Estudos ecologicos mostraram uma deficiencia dos fungos micorrizicos em monoculturas. Correlado com isso as plantas mostraram deficiencias da nutricao e multas doencas. Na base destes resultados concluimos que sera necessario manejar as populacoes dos fungos micorrizicos, que significa uma aplicacao dos fungos e uma introducao de um manejo que respeita a necessidades dos simbiontes.

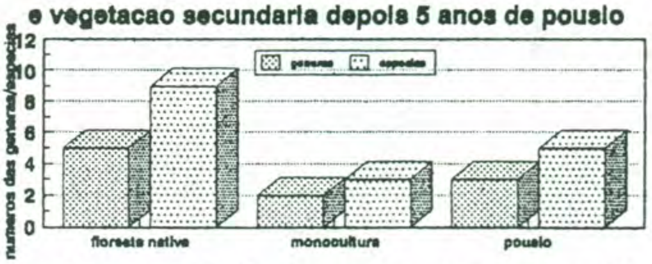


No caso da Seringueira existe uma deficiencia da micorrizacao nos plantios em comparacao com locais naturais



Numa fase de pousio (5 anos) a situacao da micorriza pareceou meilorar: a colonizacao dos raizes aumentou-se

Diversidade das populacoes dos FMVA em tres tipos de vegetacao: floresta nativa, monocultura e vegetacao secundaria depois 5 anos de pousio



Resultados preliminarios sugerem: o numero das especias dos FMVA aumenta com o numero dos hospites

Efeito dos fungos micorrizicos no crescimento dos dois cultivos Seringueira e Milho

67%	51%	68%	78%	81%	75%

Colonizacao das raizes experimental

Alem 5 anos do pousio a efectividade dos FMVA dos plantios fica muito baixa

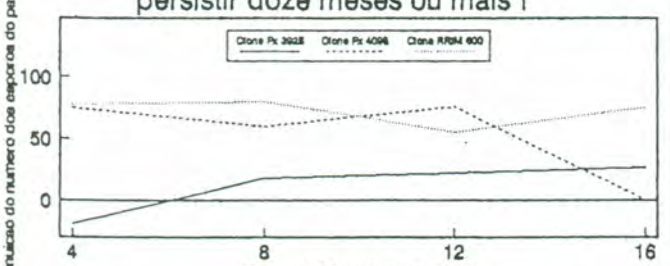
Efeito dos FMVA introduzidos em competicao com fungos micorrizicos indigenos

24%	45%	63%	76%	91%

Colonizacao das raizes experimental

Fungos micorrizicos introduzidos competem com successo com FMVA indigenos e sao mais efectivos

No practico o efeito da micorrizacao pode persistir doze meses ou mais !



30	40	38	35

Colonizacao das raizes [%]

A intensidade do efeito depende do clone !

CONCLUSAO:

- A importancia dos fungos micorrizicos para o crescimento e a saude dos hospites cria a necessidade da presentia dos fungos numa quantidade e qualidade sufficiente num sistema agricultorio.
- Porquanto uma deficiencia alta dos simbiontes existe em areas agricultorias (tambem em areas abandonadas com vegetacao secundaria), fungos efectivos tem que ser introduzidos quando uma producao dos cultivos e planejado.
- Fungos micorrizicos podem competir com fungos indigenos com bom successo, mas o produtor que usa FMVA tem que selecionar fungos efectivos.
- O efeito tem uma duracao que seria economicamente lucrativo.

Idczak, E., Feldmann, F. (1992):

Mycorrhizal status of an abandoned rubber tree plantation after slashing and burning

International Symposium "Tropische Nutzpflanzen", 20.-24.09.1993, Hamburg, FRG; Tagungsband S. 88

Mycorrhizal status of an abandoned rubber tree plantation after slashing and burning

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The importance of va-mycorrhizal fungi for the "ecological fitness" of their host plants is well known. In recultivation programs of abandoned monocultural plantations special attention must be paid to these symbiotical fungi as the mycorrhizal potential of the soil might be very low.

In case of the abandoned rubber tree plantation in the Amazon region the quantity of va-mycorrhizal spores ranges between 2 - 16 spores per cm^3 soil. However, the determination of the most probable number of infection units by means of a standardized MPN-test reveals that the infection potential six months after slashing and burning is zero. This indicates that the spores are dead or that they are in a resting state. Even nine months after slashing and burning of the abandoned rubber tree plantation the roots of different plant species of the spontaneous secondary vegetation are only colonized to a very low extent which might be due to the fact that these plants are no suitable host plants for the va-mycorrhizal fungi - grown in the field show a higher degree of root colonization.

Thus the cultivation of corn might serve as a tool to increase the number of mycorrhizal propagules in the process of recultivation. Another possibility to improve the mycorrhizal status in the field is the inoculation of the plants with va-mycorrhizal plants for plantation.

D 30

Introduction

It is intended to recultivate rubber tree plantations in the Amazon region, which have been abandoned because of their insufficient productivity caused by phytopathological problems. For the establishment of sustainable plantations on these fallows, attention mu be paid to plant beneficial microorganisms as for example vesicular-arbuscular mycorrhizal fungi (VAMF) because they influence growth and health of the plants.

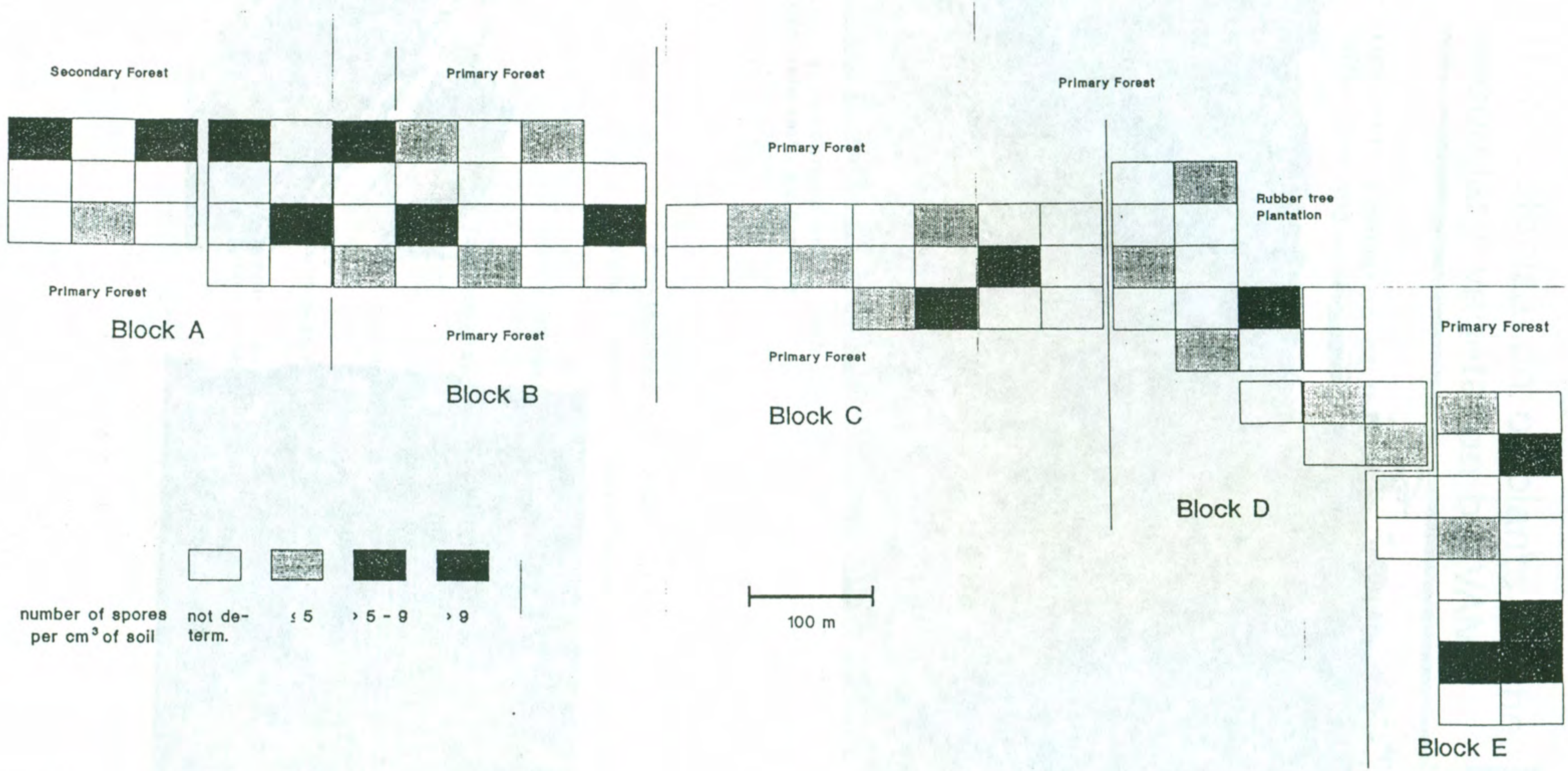
The data presented, demonstrate the mycorrhizal situ ation in the field of a former rubber tree plantation six to nine months after slashing and burning - a common method of field preparation in the tropics. Furthermore, proposals are given how to improve the mycorrhizal status in these areas.

1) Quantity of va-mycorrhizal spores and the infection potential in the soil

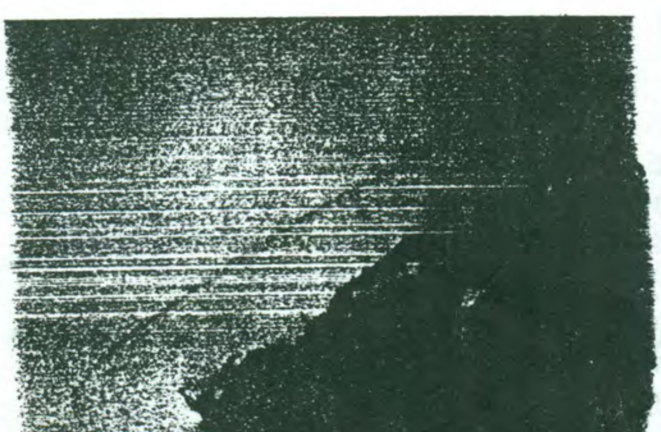
- Six months after slashing and burning of the plantation the quantity of va-mycorrhizal spores in the soil ranges between 2 and 16 spores/cm^3.

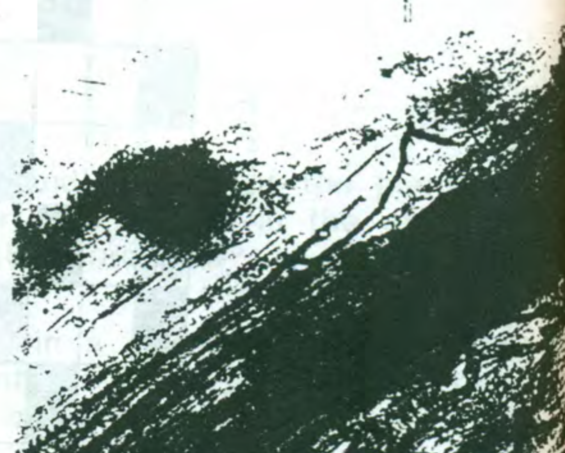
- As these spores might be in a dorminant state or even dead, the determination of the most probable number (MPN) of infection units of VAMF in the soil is necessary.

- The standardized MPN-test with corn as host plant reveals that the infection potential of VAMF in the soil is zero. However, it might be that in case of very low numbers of infection units the test period of one month is not sufficient for the fungi to colonize the host plant but that plants which grow for a longer period in the field can still be colonized. Therefore, selected species of the secondary vegetation in the field have been analysed for root colonization by VAMF.


Secondary Forest
Primary Forest
Primary Forest
Block A
Primary Forest
Block B
Primary Forest
Primary Forest
Primary Forest
Block C
Rubber tree Plantation
Primary Forest
Block D
Block E
number of spores per cm³ of soil
not determ.
≤ 5
> 5 - 9
> 9
100 m

Area of the abandoned rubber tree plantation six months after slashing and burning





Root colonization of plants of the secondary vegetation by VAMF

- The root colonization of the analysed plants nine months after slashing and burning of the rubber tree plantation is very low.

- This could be due to the extremely low infection potential of VAMF in the soil or to the fact that these plants are no suitable host plants for the VAMF and thus do not serve for their multiplication.

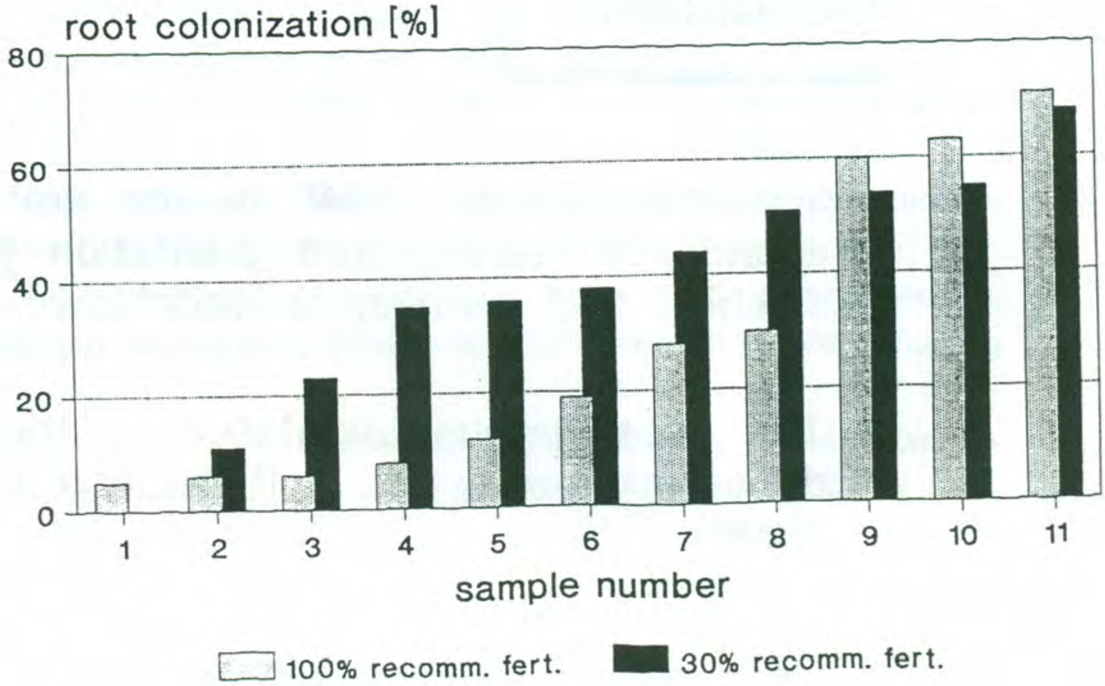
- To clarify the cause of the low degree of root colonization in species of the spontaneous vegetation, corn - a well known host plant of VAMF - has been cultivated in the field and the roots have been analysed for infection with these fungi.

growth form/ plant species	degree of root colonization [%]
stolon grasses	< 1
tussock grasses	< 1
fern *(Pteridium aquilinum)*	< 1
tree *(Vismia guianensis)*	< 1
creeping herb *(Pueraria phaseoloides)*	10-20


tussock grasses
fern
(Pteridium aquilinum)


tree
(Vismia guianensis)
creeping herb
(Pueraria phaseoloides)
stolon grasses

3) Use of corn for the multiplication of VAMF in the field



- Roots of corn grown for two months in the field are colonized up to 71% with VAMF and thus serve for the propagation of the fungi.

- The application of lower amounts of fertilizer to the crop (30% of the recommended value) results in a higher degree of root colonization compared to plants fertilized in the common way (100% of recommended amount of fertilizer).

Conclusions

- The potential of VAMF in the soil of the abandoned rubber tree plantation after slashing and burning is very low.

- The spontaneous vegetation in the field does not serve for multiplication of the VAMF.

- Corn grown in the field is heavily infected by mycorrhizal fungi and thus can serve for multiplication of the VAMF.

- Furthermore, it is possible to improve the mycorrhizal status in the field by application of inoculum of VAMF to the soil or by use of mycorrhizal plants.

Appendix 3

Feldmann, F., Idczak, E. (1992): Inoculumproduction of VAM fungi for use in tropical nurseries
In: Varma, A.K.; Norris, J.R.; Read, D.J. (eds.) : Methods in Microbiology 24: Experiments with Mycorrhizae (1992) S. 339-357

Feldmann, F., Müller, I., Idczak, E., Weritz, J. (1993d): Preparo e aplicacao de fungos micorrizicos selecionados para polyculturas perenes em Amazonia
International Symposium "Manejo e reabilitacao de areas degradadas e florestas secundarias na Amazonia" 18.-22.04.1993, Santarem, Brasil

Feldmann, F., Müller, I., Weritz, J., Macedo, J.L.V., Idczak, E. (in press): Isolation, selection and production of VAMF and their application in mixed cropping systems
Proceedings of the International Symposium "Manejo e reabilitacao de areas degradadas e florestas secunda-rias na Amazonia 18.-22.04.1993, Santarem, Brasil (in press)

18

Inoculum Production of Vesicular-arbuscular Mycorrhizal Fungi for Use in Tropical Nurseries

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I. Introduction

The use of vesicular-arbuscular mycorrhizal fungi in the production of plants for tropical use has already been tested and described by some authors (e.g. Sieverding and Saif, 1984; Hayman, 1987). Under tropical conditions (poor soils, extreme temperatures and high humidity or drought, presence of many pathogens) the use of vesicular-arbuscular mycorrhizal fungi can be especially beneficial to perennial crops which are produced in nurseries and then planted in the fields. Vesicular-arbuscular mycorrhizal fungi not only give improved growth of different tropical crops, but also show the potential to increase resistance of the host to root pathogens (Zambolim, 1986) and to reduce the severity of foliar disease (Feldmann, 1990).

Most tropical perennial crops are propagated from seeds or cuttings in nurseries before they are transferred to the plantations. These crops are normally hosts for vesicular-arbuscular mycorrhizal fungi. A list of tropical plants that act as hosts for vesicular-arbuscular mycorrhizal fungi can be found in Janos (1987). In the tropical countries Colombia and Brazil vesicular-arbuscular mycorrhizal fungi are already in some cases an important factor in commercial cultivation systems, diminishing the cost of plant production (e.g. M. T. Lin, pers. commun.) not only because the plants can be produced using smaller amounts of fertilizers, but also because there are fewer losses during production. In general mycorrhizal plants are of better quality than non-mycorrhizal ones. They are more resistant to many stress factors when they are transferred to the plantations (see e.g. Schönbeck, 1987).

Why is the use of vesicular-arbuscular mycorrhizal fungi in plant production systems not yet a common procedure? Certainly the difficulties involved in the selection of the fungi which can be used are an important factor. But probably the most important reason for their current lack of use is that potential users of vesicular-arbuscular mycorrhizal fungi are not able to handle the inoculum production themselves and there are no producers of inoculum who can guarantee a standard quality and low cost of production and transport to the users. These problems can be solved by the use of an inorganic material as a carrier for the infection units of the vesicular-arbuscular mycorrhizal fungi—so-called "expanded clay" (see Fig. 1). The method of producing inoculum with expanded clay was first described by Dehne and Backhaus (1986). In this chapter we describe our experience with this method, and how we adapted it to the conditions of the humid tropical region of Amazonas, Brazil.

With expanded clay as the carrier for propagules of vesicular-arbuscular mycorrhizal fungi it is easily possible to produce an inoculum of high quality on a large scale. High quality means first that the inoculum causes a rapid colonization of the plant root system by the vesicular-arbuscular mycorrhizal fungi. This is guaranteed by an inoculum of high infectivity. In the case of expanded clay as a carrier for propagules of vesicular-arbuscular mycorrhizal inoculum, infectivity does not necessarily mean large numbers of spores. Mycelia are very often as important as spores for root colonization (see Grunewaldt-Stöcker and Dehne, 1989). Because of this it is necessary to include a method for the estimation of all infection units (spores and mycelia). Only by such a method does the control of the infectivity of the produced inoculum

Fig. 1. Expanded clay particle. For inoculum production of vesicular-arbuscular mycorrhizal fungi broken expanded clay can be used as an organic carrier material for the fungal propagules. The fungi are sporulating inside the cavities of the clay particles. The infectivity of the inoculum depends not only on the fungal spores, but also on fungal mycelia on the surface of the particles. Bar, 0.2 cm.

become convincing. For this purpose the use of the most probable number method (MPN test), described below, is recommended.

The second very important characteristic of an inoculum of high quality is that it should be uncontaminated or contain only small quantities of plant pathogenic micro-organisms. Depending on the purpose for which the inoculum is produced, a low level of contamination can be ignored. If, for example, it is to be used for the inoculation of young cuttings for seedlings in nurseries, it has to be pure because these plants are in most cases extremely susceptible to pathogenic fungi during the first weeks of growth. The use of expanded clay as a carrier for infection units of vesicular-arbuscular mycorrhizal fungi makes it possible to avoid contamination of the substrate by pathogens during inoculum production and to decontaminate it selectively if contamination has taken place during production.

The method described here can also be used in temperate climates. Some of the special adaptations to tropical conditions are normally not necessary in this case (e.g. reduction of evaporation from the pots). Inoculum produced by the procedure described below proved to be very suitable for successful colonization of the following tropical perennial crops (annual crops are not listed): *Hevea brasiliensis* (rubber, seringueira) *Carica papaya* (papaya, mamao), *Manihot esculenta* (cassava, manioca), *Citrus* spp. (e.g. orange, laranja), *Theobroma cacao* (cacao), *Theobroma grandiflorum* (cupuacu), *Elaia guianensis* (oil palm, dende), *Guilielma gassipaes* (pupunha).

II. Inoculum production with inorganic carrier material

A. Materials

Broken expanded clay (Leca) was used as the carrier material for the infection units of the vesicular-arbuscular mycorrhizal fungi, as proposed by Dehne and Backhaus (1986). The particle size was between 4 and 8 mm in diameter. Other expanded clay material seems not to work so well, perhaps because of a different surface structure.

The host plant used was normally corn (*Zea mays*, variety "Badischer Landmais" or the Brazilian hybrid BR 5102).

The vesicular-arbuscular mycorrhizal fungi available in mass production with expanded clay are listed in Table I.

The infectivity of the inoculum depends on the chosen isolate of the vesicular-arbuscular mycorrhizal fungus; isolates with between 0 and 5 infection units per cm^3 in expanaded clay showed higher numbers of propagules when cultivated in sand.

B. Initial phase of inoculum production

The first step in inoculum production of vesicular-arbuscular mycorrhizal fungi is the colonization of host roots by the selected fungi. The plants are grown in a sandy substrate and planted into the clay substrate later in the second phase of mass production. Small quantities of defined fungal material or small samples of undefined soil are sufficient for the

TABLE I

Inoculum infectivity of different vesicular-arbuscular mycorrhizal fungal species in expanded clay as a carrier for the infection units

Vesicular-arbuscular mycorrhizal fungus	Isolate	Source	Inoculum infectivity[a]
Glomus etunicatum	D13	Dehne	***
	T 6	Dehne	***
	476	Schenck	*
Glomus intraradices	208	Schenck	**
	267	Schenck	***
Glomus manihotis	W 9	Weritz	**
Gigaspora margarita	185	Schenck	*

[a]The infectivity of the inoculum was assessed by the MPN-method (described below). The meaning of the symbols is: ***, more than 30 IU cm^{-3}; **, 5–30 IU cm^{-3}; *, 0–5 IU cm^{-3}. IU are infection units (spores, vesicles and mycelia (see below)).

colonization of the host plants. Pure defined isolates of vesicular-arbuscular mycorrhizal fungi can be produced by single-spore cultivation, using material received from other laboratories or bought from specialist companies.

The procedure is as follows:

- Seeds of the host plants are prepared for use in inoculum production by washing for 12 h under running water to remove all pesticides. After this period the seeds are thoroughly soaked and can be sown.
- Small pots of size 7 cm × 10 cm × 10 cm are cleaned intensively, especially if they have been used previously.
- A 3 cm layer of sand is added to the bottom of the pot. A 1 cm depth of substrate containing the start inoculum is then layered on the sand.
- The prepared seeds are sown and covered with sand. The optimal number of plants is 10 per pot.

After a few days the plant roots grow through the inoculum layer and later fill the whole volume while the fungi intensively colonize them. After three weeks the initial phase of inoculum production normally ends and the host plants are ready to be prepared for the second phase of mass production using expanded clay as substrate (see Fig. 2).

Remarks

If fungal material of low infectivity is used in this initial phase of inoculum production, the roots of the host plants may not be well colonized after 21 days of growth. In this case it is necessary to leave the host plants in the small pots for five weeks before mass production starts. If mixed populations of vesicular-arbuscular mycorrhizal fungi are used as start inoculum in the initial phase the fungi which will be multiplied in the following mass production may be selected by the speed with which they colonize the roots.

The cultivation parameters (e.g. irrigation, fertilization, etc.) in the initial phase can be deciding factors for the future quality of the inoculum. In our experience a substrate temperature of between 22 and 24 °C is optimal. In growth chambers the air temperature may be 24 °C while that of the substrate is much lower because of the cooling stream of air! Mycorrhizal fungi normally are less infective under such conditions.

The humidity of the substrate should be a little below field capacity. The young plants require fertilizer, especially if they are grown for

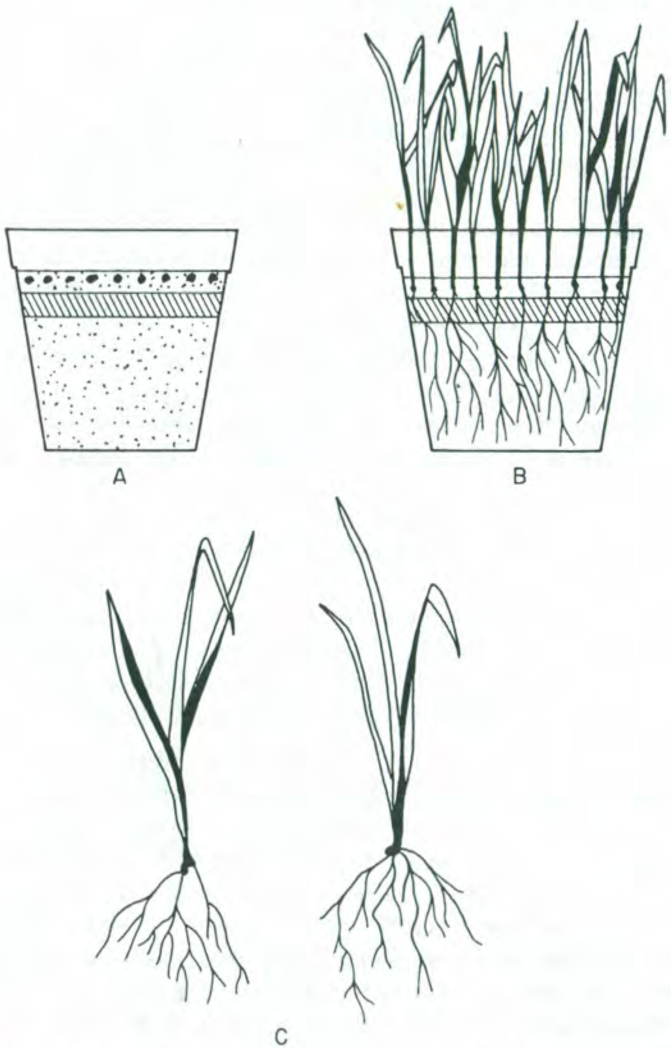

Fig. 2. The initial phase of inoculum production. (A) Small pots are partially filled with sand, the starter inoculum layered on the top. Corn seeds are then sown and covered with sand. (B) The corn seedlings are grown for 3–4 weeks in the small pots until their roots are colonized by the vesicular-arbuscular mycorrhizal fungi. (C) When the roots are colonized they are separated from each other by washing them thoroughly under running water. The roots can then be surface sterilized.

more than two weeks in small pots. We use the nutrient solution described below for mass production but diluted 1:5 and applied twice a week at 20 ml per pot (or more, if the plants show symptoms of deficiency).

An important factor in the initial phase of inoculum production is the period and intensity of irradiance. We obtain the best colonization under irradiance of an intensity of 12 000–15 000 lx from mercury vapour lamps for 14 h day^{-1} (200–260 $\mu E\, m^{-2} s^{-1}$). Dehne and Backhaus (1986) recommended an intensity of 5000 lx for 16 h day^{-1}. We find this to be insufficient for optimal root colonization by mycorrhizal fungi.

C. Mass production

1. *Separation of the host plants*

In the first step of mass production the plants from the initial phase have to be separated from each other. This is easily achieved if they are washed carefully under running water.

2. *Sterilization of the host plants*

The root systems of host plants from the initial phase of inoculum production can be surface sterilized after separation to avoid the transfer of pathogenic micro-organisms into the expanded clay substrate. Dehne and Backhaus (1986) propose ethanol (70%) for 2 min against *Pythium ultimum*; we use—if necessary—a solution of sodium hypochlorite (2%) for 2 min. If the initial phase of inoculum production is quite short (up to three weeks) and the conditions controlled (as in growth chambers) it is normally not necessary to surface sterilize the root systems of the host plants before planting them into the expanded clay.

3. *Preparation of expanded clay for mass production*

Before the host plants are planted into the expanded clay the substrate should be washed. Pasteurization can be an advantage, but is not always necessary. Only if a test with agar plates shows contamination with pathogenic or saprophytic fungi is fumigation essential. We sterilize the expanded clay twice for 4 h with steam. Between the two fumigations the clay is cooled down to 20 °C.

After washing and sterilization the expanded clay is placed into 5-litre pots. Larger containers are also practical. We prefer the 5-litre size because the root systems of two corn plants grow intensively through the whole volume of the pots during the period of inoculum production.

4. Planting of the host plants

Two host plants whose root systems have been colonized by the vesicular-arbuscular mycorrhizal fungi in the initial phase are planted into each pot which has been filled with 5 litres of expanded clay. This has to be done very carefully to avoid damage to the roots by the very rough clay particles. Afterwards the substrate is watered thoroughly to fix the plants.

5. Cultivation parameters

Five basic requirements must be fulfilled to allow the production of inoculum of high quality:

(a) The illumination of the plants must be optimal.
(b) The optimal temperature range of the fungi in the substrate should be exceeded only for short periods of time.
(c) Long-term drought and waterlogging of the substrate must be avoided.
(d) The plant nutrition must be optimal for the symbiosis.
(e) The plants must be treated against pathogens.

(a) Optimal illumination. In temperate climates mass production independent of environmental conditions is possible in greenhouses with additional illumination. Dehne and Backhaus (1986) used sodium vapour high-pressure lamps with an intensity of 5000 lx for 16 h per day as an additional light source. We found that 14 h of light per day with an intensity of 10 000 lx or more (200–260 $\mu E\, m^{-2}\, s^{-1}$) generated by mercury vapour lamps improved the quality of inoculum produced in the greenhouse. In temperate climates during the summer we successfully produced inoculum of high quality and in large quantities in small plastic greenhouses. The covering material of the greenhouse was a film (Wepelen GF3, Werra-Plastik, Philippsthal, FRG) which allows sufficient light transmission above 350 nm (Idczak *et al.*, 1988). Therefore an additional light source was not necessary.

In the humid tropics, however, several complications with regard to interactions between environmental parameters and symbiont growth occur which require special adaptations. For example, intensive irradiation results in high temperatures in the greenhouses, which are not normally air-conditioned. This has a detrimental effect on plant growth. Shading the greenhouses results in decrease of irradiation. Therefore mass production outdoors is advisable. With varieties of corn adapted to these conditions the whole solar spectrum can be utilized. When the

pots with expanded clay are placed outside (if necessary an acclimatisation period of the plants to the outdoor conditions must be taken into account) they must not have any contact with the ground so that mud splashes and soil fauna cannot contaminate them and the purity of the produced inoculum can be assured (see Fig. 3).

(b) Temperature of the substrate. Under direct irradiation the temperature of the substrate might attain a level which has a negative influence on development of the symbiosis. To avoid this shading of the pots is recommended, e.g. by placing them into a wide, well-aerated trough (see Fig. 3).

(c) Irrigation. A problem in the use of expanded clay as a substrate is the low potential for water transport from the bottom of the container to the upper layers of the substrate (larger particle size in the upper layers). On the other hand, much water can be held in the lower layers of the substrate, which consists mainly of smaller particles. Because of this the lower layers may be temporarily too wet. Regular drying out can be achieved by the use of clay pots instead of plastic containers. To reduce evaporation from the surface of the substrate the pots should be

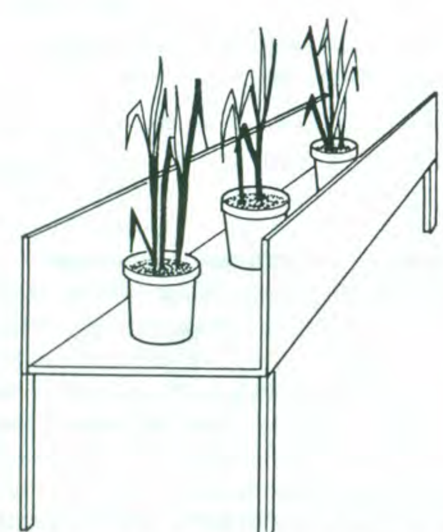

Fig. 3. Trough made of wood. A trough like the one shown guarantees that contamination of the inoculum by soil fauna and splashing mud is largely avoided during inoculum production. It can be constructed to provide shade for the pots while retaining adequate air flow around them.

covered with a white plastic film with holes which limits gas exchange between substrate and air but does not prevent it completely. In this way the plants need watering only once a day or less. The amount of water necessary for the plants depends on the prevailing transpiration and evaporation. Substrate humidity should always be kept a little below the field capacity of the expanded clay.

(d) Plant nutrition. Adequate plant nutrition is guaranteed by use of a fertilizer (modified after Hoagland and Arnon, 1938) added to the water three times a week. In the nutrient solution the proportion between the main macronutrients should be as follows:

N:P:K as 1:0.85:3.35

with a concentration of

83 mg N litre^{-1}, 31 mg P litre^{-1} and 232 mg K litre^{-1}

Two to three times a month a stock solution is prepared which contains

KNO_3	50.0 g litre^{-1}
$Ca(NO_3)\cdot 4\ H_2O$	11.6 g litre^{-1}
KH_2PO_4	12.4 g litre^{-1}
$MgSO_4\cdot 7\ H_2O$	49.3 g litre^{-1}
Fe-citrate/Fe EDTA	8.0 g litre^{-1}
$MnSO_4\cdot 1\ H_2O$	0.15 g litre^{-1}
$ZnSO_4\cdot 7\ H_2O$	0.02 g litre^{-1}
$CuSO_4\cdot 5\ H_2O$	0.08 g litre^{-1}
$Na_2B_4O_7\cdot 10\ H_2O$	0.2 g litre^{-1}
$(NH_4)_6Mo_7O_{24}\cdot 4\ H_2O$	0.2 g litre^{-1}
$CoNO_3\cdot 6\ H_2O$	0.25 g litre^{-1}

The pH of the nutrient solution is adjusted to 5.5 with HCl.

A commercially available fertilizer (Flory 9) with a similar composition of nutrients as given above can be applied to the plants for inoculum production with expanded clay. It may be anticipated that other commercial fertilizers, too, are suitable to circumvent the time-consuming preparation of the nutrient solution. It is critical to make sure that the concentrations of P and N do not exceed maximum levels of 70 ppm for P and 50 ppm for N in the substrate as this might be detrimental to the colonization of the roots.

(e) Treatment against pathogens. Once a month the plants are watered with an added fungicide (Previcur, 0.15%) selective for oomycetes such as *Pythium*, an important plant pathogen which can occur in the

substrate during inoculum production. No effect of Previcur on the mycorrhizal fungi has been detected. Other fungicides can be used, only with caution! Negative effects have been shown for Captan, Captafol, Thiabendazol, Formaldehyde, Maneb, Chlorothalonil (Nemec, 1980) and Benomyl (Fitter and Nichols, 1988). Our preliminary investigations show negative effects of the fungicides Bayleton, Cercobin and (in higher concentrations) of the herbicides Gramoxon and Round up (for further data, see Nemec, 1987).

Sometimes contamination of the substrate by saprophytic or pathogenic fungi can be observed during inoculum production. The presence of saprophytes and pathogens can be revealed by a growth test on agar. If contamination has taken place it is possible to treat the expanded clay with ethanol (70%) as Dehne and Backhaus (1986) propose. We have observed good results by using sodium hypochlorite (2%) for 2–5 min and washing afterwards. However, this procedure also reduces the infectivity of the inoculum. It is much less complicated and cheaper to avoid contamination during inoculum production by maintenance of clean conditions and appropriate irrigation.

6. *Growth period and harvest*

Mass production of inoculum in containers with expanded clay as substrate takes 3–4 months, depending on the growth of the host plants. A macroscopical check on root colonization by vesicular-arbuscular mycorrhizal fungi is possible as corn roots often show an increasing yellowish colouring as the symbiosis develops. But to make sure that the roots really are colonized they should be cleared and stained for detection of the fungi (see below). If the roots are well colonized no further irrigation is necessary. The drought stress will stimulate spore production. After the first week of the drought period the plants are cut. Three weeks later the substrate should be spread out in a thin layer to be air-dried rapidly (see Fig. 4).

An important step is the separation of the roots from the expanded clay. We have repeatedly noticed increasing occurrence of pathogenic and saprophytic fungi if the roots remain in the substrate. If the inoculum produced shows high purity, i.e. no or little contamination by pathogens, the remaining roots increase the infectivity of the inoculum as they act as an additional source of infection units. Therefore we recommend testing the contamination of the inoculum by pathogens first and then deciding whether the roots should be separated from the expanded clay or not. Rapid drying of the substrate reduces growth of saprophytic fungi.

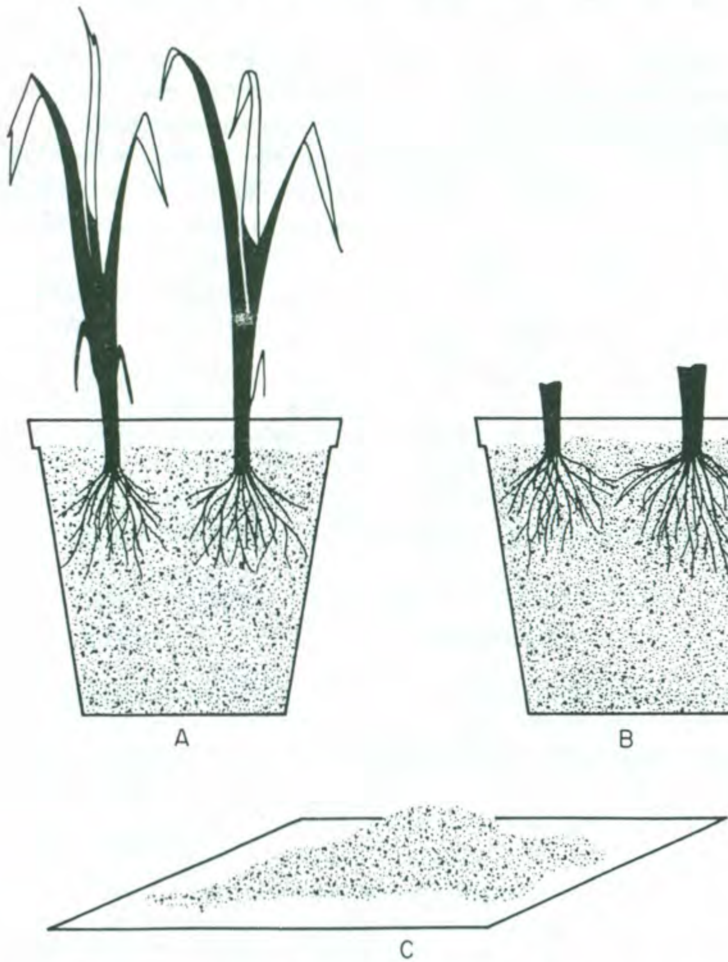

Fig. 4. The mass production of vesicular-arbuscular mycorrhizal fungal inoculum. (A) Two plants are grown in each pot (5-litre volume) for 3–4 months. (B) After the growth period the plants are not watered further. One week later they are cut. The substrate is dried for three weeks in the pots. (C) After the drought period the expanded clay is spread out in a thin layer and air-dried rapidly. The dry inoculum can be stored for a long time in a cool, dry place.

7. *Storage of the inoculum*

Storage of the inoculum under dry and cool conditions is possible for several years without significant loss of infectivity. As an example we found that the infectivity of an inoculum (*Glomus etunicatum*) which

was stored at 20–23 °C and 30–50% relative humidity for three years was reduced by only 10–15% .

III. Control of inoculum infectivity

To determine the infectivity of a produced inoculum is of great importance for application in the field and in nurseries, as well as for scientific purposes. In practice one always has to deal with economic aspects. In the case of the application of vesicular-arbuscular mycorrhizal inoculum in the field and in nurseries costs can be minimized by using the minimum amount of inoculum needed to guarantee the colonization of the host plant. Therefore the infectivity of the inoculum has to be tested. If the inoculum is used for scientific research its infectivity must be known to standardize experimental conditions.

A method often used for the estimation of the infectivity is to determine the spore numbers in the substrate. This can be carried out quickly by a wet sieving and decanting procedure and a few centrifugation steps. When expanded clay is used as a carrier for the vesicular-arbuscular mycorrhizal inoculum even the determination of the spore number in the substrate is impossible as spores are mainly formed inside the numerous cavities of the expanded clay, from which they cannot readily be removed (see Grunewaldt-Stöcker and Dehne, 1989). This circumstance and the fact that many other propagules (mycelia, vesicles) are attached to the substrate require another method for determining the infectivity of the inoculum. The most probable number method (MPN test) has been adapted to the special conditions that exist when expanded clay is used as a carrier for fungal propagules.

A. The MPN test

This test determines the infectivity of different dilutions of an inoculum and finally calculates the number of propagules in the original sample by mathematical means.

To determine the most probable number of propagules per cm^3 of expanded clay the following are required: 20 pots (volume 70 cm^3); 40 pre-soaked corn seeds; sterile expanded clay; and the expanded clay inoculum to be tested. From the original inoculum dilutions of 0, 1/10, 1/100 and 1/1000 are prepared. The 1/10 dilution is made by mixing one part of the inoculum and nine parts of sterilized expanded clay. One part of this mixture is mixed together with nine parts of sterilized expanded clay to give the next higher dilution, and so on. It is very important to mix the inoculum and the sterile expanded clay thoroughly to guarantee its homogeneous distribution.

The dilution samples are filled into pots (five pots per dilution). Then two pre-soaked corn seeds are planted in each pot. This bioassay is incubated for 30 days at 23 °C with 14 h of light per day (>200 μE m^{-2} s^{-1}). The plants are watered moderately. After the first 10 days 20 ml fertilizer of the nutrient solution described above (1/5 diluted) are added at weekly intervals. The plants are incubated for exactly four weeks and all root systems are then harvested separately. To allow microscopical assessment of root colonization by vesicular-arbuscular mycorrhizal fungi all the roots are cleared for 10 min at 90 °C in 10% KOH, rinsed with tap water and stained in 0.05% trypan blue in glycerol–lactic acid–distilled water (2:2:1) for 15 min at 90 °C.

B. Calculation of the MPN of propagules

Microscopical examination shows if a root system is colonized by vesicular-arbuscular mycorrhizal fungi. For the five replicates in each of the four dilutions one might obtain a combination of numbers such as:

5 5 3 2

This means that all root systems are colonized in dilutions 0 and 1/10, three root systems are colonized in the dilution 1/100, and two in the dilution 1/1000.

For the calculation of the MPN of propagules only three numbers of the given combination are required. The first number (N1) is that corresponding to the least concentrated dilution in which all (or the greatest number of) root systems are colonized. The two other numbers (N2 and N3) are those corresponding to the next two higher dilutions. In our example it would be the combination:

N1 N2 N3

5 3 2

Making use of Table II with these values of N1, N2 and N3, we find the value given for the combination 5 3 2 is 1.4. This is the most probable number of propagules in the second dilution of the combination used, which in our example is 1/100. To obtain the MPN for the original sample, the value is multiplied by the appropriate dilution factor. In our case the original sample would have an MPN of

$$1.4 \times 100 = 140 \text{ propagules cm}^{-3}$$

TABLE II
Most probable numbers for use with 10-fold dilutions and five pots per dilution (Cochran, 1950)

N1	N2	Most probable number for indicated values of N3: 0	1	2	3	4	5
0	0	–	0.018	0.036	0.054	0.072	0.090
0	1	0.018	0.036	0.055	0.073	0.091	0.11
0	2	0.037	0.055	0.074	0.092	0.11	0.13
0	3	0.056	0.074	0.093	0.11	0.13	0.15
0	4	0.075	0.094	0.11	0.13	0.15	0.17
0	5	0.094	0.11	0.13	0.15	0.17	0.19
1	0	0.02	0.04	0.06	0.08	0.10	0.12
1	1	0.04	0.061	0.081	0.10	0.12	0.14
1	2	0.061	0.082	0.10	0.12	0.15	0.17
1	3	0.063	0.10	0.13	0.15	0.17	0.19
1	4	0.11	0.13	0.15	0.17	0.19	0.22
1	5	0.13	0.15	0.17	0.19	0.22	0.24
2	0	0.045	0.068	0.091	0.12	0.14	0.16
2	1	0.068	0.092	0.12	0.14	0.17	0.19
2	2	0.093	0.12	0.14	0.17	0.19	0.22
2	3	0.12	0.14	0.17	0.20	0.22	0.25
2	4	0.15	0.17	0.20	0.23	0.25	0.28
2	5	0.17	0.20	0.23	0.26	0.29	0.32
3	0	0.078	0.11	0.13	0.16	0.20	0.23
3	1	0.11	0.14	0.17	0.20	0.23	0.27
3	2	0.14	0.17	0.20	0.24	0.27	0.31
3	3	0.17	0.21	0.24	0.28	0.31	0.35
3	4	0.21	0.24	0.28	0.32	0.36	0.40
3	5	0.25	0.29	0.32	0.37	0.41	0.45
4	0	0.13	0.17	0.21	0.25	0.30	0.36
4	1	0.17	0.21	0.26	0.31	0.36	0.42
4	2	0.22	0.26	0.32	0.38	0.44	0.50
4	3	0.27	0.33	0.39	0.45	0.52	0.59
4	4	0.34	0.40	0.47	0.54	0.62	0.69
4	5	0.41	0.48	0.56	0.64	0.72	0.81
5	0	0.23	0.31	0.43	0.58	0.76	0.95
5	1	0.33	0.46	0.64	0.64	1.1	1.3
5	2	0.49	0.70	0.95	1.2	1.5	1.8
5	3	0.79	1.1	1.4	1.8	2.1	2.5
5	4	1.3	1.7	2.2	2.8	3.5	4.3
5	5	2.4	3.5	5.4	9.2	16.0	–

C. Critical factors in the MPN test

1. *The host plant*

The choice of the host plant used for the MPN test can have a dramatic influence on the results. A strict specificity between a vesicular-arbuscular mycorrhizal fungus and certain plant species does not exist but some preferences for plant species and for varieties of a particular species by defined vesicular-arbuscular mycorrhizal isolates have been found (Azcon and Ocampo, 1981). The best choice of a host plant for the MPN test would be a plant species for which the vesicular-arbuscular mycorrhizal inoculum is produced. In cases of trees and plants cultivated from cuttings this may not be practical because of the time taken for their development. Therefore fast-growing plants of low specificity such as corn or onion are frequently used for the bioassy. These are known to be colonized heavily by a wide range of vesicular-arbuscular mycorrhizal fungi. If comparing the infectivity of different vesicular-arbuscular mycorrhizal inocula, the same host plant must be used in any case.

2. *The incubation period*

The propagules of the inoculum tested need some time to colonize the roots of their host plants—time for germination of the spores, time for growth of mycelium and time for penetration of the roots. The time period necessary for these developmental stages may vary between different vesicular-arbuscular mycorrhizal isolates. If the chosen incubation period for the MPN test is too short the number of propagules will be underestimated—if the incubation period is too long infections occur in the root systems of all plants in the MPN test, even in the higher dilutions, and the number of propagules is overestimated. A compromise is inevitable. We found the incubation period of 30 days recommended by Porter (1979) suitable for all purposes.

3. *The distribution of the inoculum*

Because of the relatively large particle size of expanded clay (4–8 mm diameter) the homogeneous distribution of propagules in dilutions is difficult. As a consequence, the number of propagules may be underestimated if the root system does not grow through the whole pot and misses the few expanded clay particles in a high dilution which carry vesicular-arbuscular mycorrhizal propagules.

IV. Discussion

Expanded clay as the carrier for the vesicular-arbuscular mycorrhizal propagules allows easy production of qualitatively excellent inoculum. Several advantages speak in favour of the use of expanded clay for inoculum production compared to conventional substrates such as soil or peat–vermiculite mixtures:

- The purity of the inoculum can be maintained without difficulty, contamination by pathogens can be largely avoided and decontamination afterwards is possible.
- The low weight of expanded clay allows easy long-distance transport and distribution of large quantities of inoculum.
- Inoculum can be stored for a long period without loss of infectivity.
- Application is very simple. The large particle size facilitates control of a homogeneous distribution of the inoculum in the substrate of inoculated plants.
- The high numbers of propagules (30–50 propagules per 8–10 particles of expanded clay, i.e. per cm^3 expanded clay) permit the use of low doses of inoculum. Successful inoculation of a host plant requires 2–5 vol% of expanded clay with an MPN of approximately 30 propagules per cm^3.

All these considerations highlight the possibility of introducing the use of mycorrhizal fungi easily where their effect is likely to be greatest—in tropical climates, where several physical stresses lead to poor conditions for the cultivation of plants. Users can be taught the method of application very quickly because the handling of the inoculum is very simple. The method of inoculum production described above can be used immediately by specialized staff of centralized agricultural institutions, which can also distribute the expanded clay inoculum to farmers without great effort.

The use of expanded clay inoculum is of most value in nurseries, where vesicular-arbuscular mycorrhizal fungi can be introduced to different plants successfully. Application in the field requires the use of selected and adapted fungi. Mycorrhizal plants which are produced in nurseries are less susceptible to transplantation stress than non-mycorrhizal plants (see e.g. Hayman, 1987). This is also the case if the fungi used are not adapted to the conditions prevailing at the final planting site, although these fungi are often suppressed by competitive indigenous fungi after some time (Feldmann, 1990).

Expanded clay inoculum is suitable for field application in both temperate climates (Baltruschat, 1987) and the tropics. Even smallest quantities of inoculum (less than 1 cm^3 of expanded clay per two corn seeds) caused significant additional yield of mycorrhizal plants on Brazilian latosols (J. Weritz, pers. commun.) Expanded clay used in this way as starter inoculum offers the possibility for field production of large quantities of soil inoculum. In a yellow latosol the number of vesicular-arbuscular mycorrhizal propagules per cm^3 soil was increased from 4 to 75 with corn as the host plant. The fungi involved, *Glomus etunicatum* and *G. manihotis*, were bound to the expanded clay particles and could be harvested for use as vesicular-arbuscular mycorrhizal inoculum (Feldmann, 1990).

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ISOLATION, SELECTION AND PRODUCTION OF VESICULAR-ARBUSCULAR MYCORRHIZAL FUNGI (VAMF) AND THEIR APPLICATION IN MIXED CROPPING SYSTEMS

by

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Summary

The introduction of vesicular-arbuscular mycorrhizal fungi (VAMF) into agricultural systems benefits the growth and the health of the crops, especially in abandoned areas with poor soils. As a pre-requisite for the application of the symbionts, the fungi must be isolated and selected with respect to their efficiency for the plants and their adaptability to the environmental conditions in the field.

Different methods of isolation and the selection procedure are described. The mass production of the selected fungi can be carried out in the greenhouse or in the field. The inoculation of the plants with the VAMF is possible in the nurseries as well as in the field. Two methods of application - inoculation of the plants with a homogeneous mixture of the inoculum in the substrate and with a concentrated inoculum layer respectively - are presented.

Introduction

In tropical habitats the benefits of vesicular-arbuscular mycorrhizal fungi (VAMF) to their host plants are of special importance. By means of improved nutrient supply the fungi cause significant growth enhancement of the plants in the poor soils of the tropics (Sieverding 1987, Lin 1986). Furthermore, the colonization of roots by mycorrhizal fungi increases the resistance of the host plants against root pathogens (Zambolim 1986) and reduces the severity of foliar disease (Feldmann 1991). The tolerance of mycorrhizal plants against stress (e.g. extreme temperatures, high humidity or drought and transplanting) is generally higher compared to non-mycorrhizal plants (Schönbeck 1987, Müller 1991). In agricultural systems a high deficiency of the symbiotical fungi has been observed (Feldmann 1991). To regain the "vitality of the soil" with respect to VAMF, the application of the fungi at the time of sowing or planting or even earlier in the nurseries is necessary. In Manaus, AM, a mixed cropping system of perennial plants has been installed in which the management takes account of the requirements of the fungi (less fertilization, less pesticides, more secondary vegetation). The plantation has been established in an abandoned area (former rubber plantation). To improve the "ecological fitness" of the plants, they have been inoculated with VAMF in the nursery or at the time of planting into the field.

So far the use of VAMF in plant production systems and agriculture is not a common practice. This is mainly due to the difficulties involved in the isolation, selection, multiplication and application of the VAMF. The purpose of this paper is to demonstrate the methods from the first step of isolation of the mycorrhizal fungi to the final step of application in the nurseries and in the field.

Isolation of vesicular-arbuscular mycorrhizal fungi (VAMF)

VAMF can be used in the form of

- pure isolates derived from single or multiple spore cultures of one fungal species
- a mixture of defined pure isolates
- a mixture of unknown VAMF species with proven stability of the population and its effects.

The establishment of pure isolates (1) and isolates of an unknown mixture of VAMF (2) is shown in figure 1. In both cases the origin of the fungi is field soil. Besides the living VAMF spores, field soil often contains large numbers of dead spores of mycorrhizal fungi. As it would be time consuming to establish single spore isolates directly from the original soil sample, we prefer to enhance the number of living spores by cultivation of a host plant (e.g. corn, onion, bell pepper) in the soil. This will cause the propagation of the fungi in the substrate. A disadvantage of this method at increasing the number of living VAMF spores is the possibility of pre-selection of those fungi which are more adapted to the given growth conditions. To minimize this pre-selection, the use of different plant species and growth conditions is recommended. Four to eight weeks after sowing or planting, the plant roots will be colonized by the VAMF. For the establishment of pure isolates, the plants are taken from the substrate and the roots are rinsed thoroughly. To avoid contamination with root pathogens a surface sterilization (e.g. with ethanol) of the roots can be an advantage. The plants are then transplanted into plastic sacks or other containers such as pots or boxes containing a porous substrate. They are irrigated moderately and fertilized once a week with a low phosphate fertilizer (< 60ppm P). After a growth period of eight weeks, the plants are not watered further, thus inducing the spore production of the VAMF. The spores can be removed from the substrate by the method of wet sieving and centrifugation (Daniels and Skipper 1984, Feldmann 1991). To establish pure cultures, the procedure described is repeated with a single spore as the inoculum source (single spore isolate) or with several spores of the same fungal species (multiple spore isolate), which is often problematic as it is hard to determine whether similar spores belong to the same species.

For the production of a VAMF-isolate containing an unknown mixture of VAMF species (2), several steps of the procedure described above can be omitted (see fig. 1). Furthermore, it is possible to extract the VAMF spores directly from the field soil and use them as the primary inoculum. This method will diminish the contamination with pathogens which might be present in the soil.

Before the established VAMF-isolates can be used in nurseries or on an agricultural scale, they must be selected with respect to their effectiveness.

Selection of effective VAMF-isolates

Although the VAMF are distributed worldwide and most of the plant species live in symbiosis with these fungi, a specificity in the interaction between fungus and host plant exists (Estaún et al. 1987, Graw et al. 1979, Idczak 1992). Specificity is revealed with respect to

- the host plant (plant species/ plant cultivar)
- the nature of the effect (which also depends on the environmental conditions).

Therefore the selection of effective VAMF isolates is necessary.

The selection procedure:

- List:

  * the nature of the effect(s) desired (e.g. plant growth enhancement, increase of resistance against pathogens...),
  * the given abiotic factors during the selection which should be similar to the final conditions under which the fungi will be used (substrate, temperature, pH...)

- Ensure the infectivity of the fungal inoculum which will be tested (check whether a potential host plant, e.g. corn, is colonized by the fungi).
- Determine whether the plant for which the fungal isolate is to be selected is mycotroph (Janos 1987, Feldmann 1991), i.e. test whether the VAMF are able to colonize the roots and whether the mycorrhizal plants benefit from the symbiosis.
- If the plant is mycotroph, analyse the degree of mycorrhizal dependency (obligate or facultative dependency, Feldmann 1991)
- Determine again the abiotic selection factors, considering the degree of dependency, the conditions in the area where the fungi will be used and the kind of management.
- Compare the effectiveness of the isolates with respect to the desired effect.

In addition to the described steps in the selection of effective VAMF isolates, there are other factors which should be taken into account during the selection process, such as the competitive ability and persistence of the fungi under natural conditions (Abbot et al. 1992). Once a VAMF isolate has been chosen, inoculum production on a large scale is a pre-requisite for the application in nurseries or in the field.

Inoculum production

A detailed description of the production of VAMF inoculum for use in the tropics has been presented by Feldmann and Idczak (1992). Therefore only the main aspects of inoculum production are described here.
The inoculum production can be differentiated into an initial phase (fig. 2) and mass production (fig. 3).

Initial phase:

- Fill two thirds of a pot (volume about 500 ml) with quartz sand and layer the start inoculum (soil containing the VAMF, infected root pieces or fungal spores) on top.
- Surface sterilize the seeds of a host plant (e.g. corn or onion), rinse them with water afterwards to remove all pesticides, sow them into the pots and cover them with sand.
- Water the pots moderately (the humidity of the substrate should be a little below field capacity) and fertilize the plants with a low phosphate fertilizer (P < 60ppm, details see Feldmann and Idczak 1992). Avoid the use of pesticides.
- After a growth period of three to four weeks, the roots of the host plants should be colonized by the VAMF. Control the root colonization with a microscope. In the event of low infectivity of the start inoculum the culture period can be extended by one to two weeks.
- When the roots of the host plant are well colonized, separate the plants from each other and wash the roots. Sometimes it might be necessary to surface sterilize the roots (70% ethanol, two minutes) to eliminate pathogenic microorganisms.

The plants treated in this way are used for the mass production of VAMF inoculum.

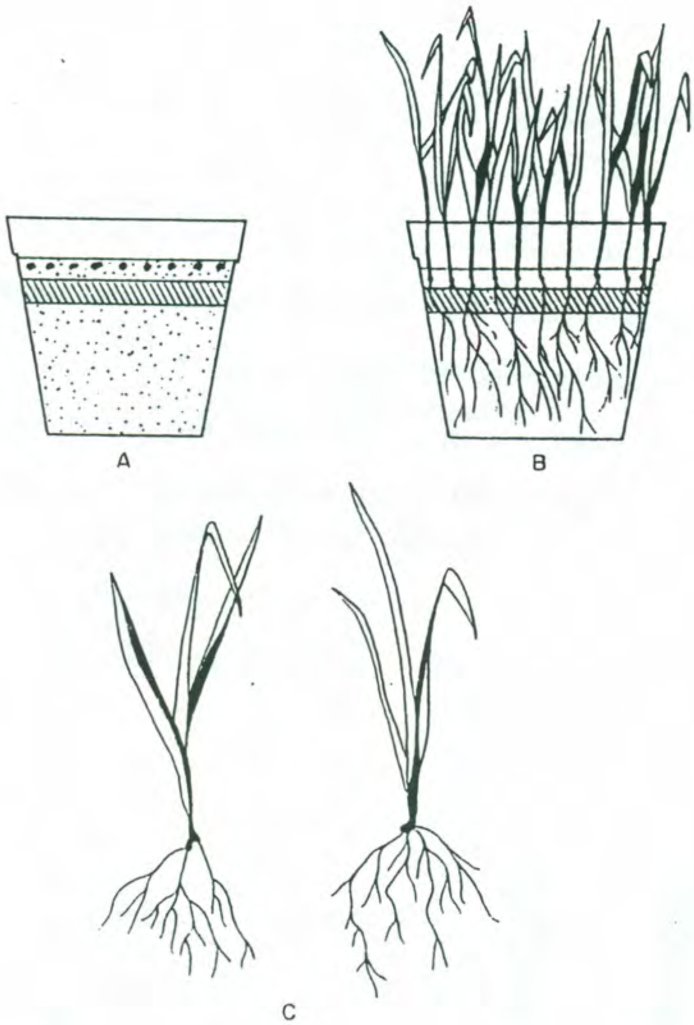

Fig. 2: Initial phase of inoculum production (Feldmann & Idczak 1992). See text for details.

Mass production:

- The mycorrhizal plants are transplanted into larger pots (volume about 5l) or comparable containers, which might be even larger, but still allow the roots to explore the whole volume (A). The use of expanded clay as the substrate (method described by Dehne and Backhaus 1986) has various advantages such as its low weight, easy application and the fact that contamination by pathogens can be largely avoided and subsequent decontamination is also possible. But other substrates like sterilized sandy soils can be used as well.
- Irrigation and fertilization should be carried out as described above (initial phase).

- After three to four months of plant growth, the roots should fill the whole volume of the container. From this moment on, the plants are no longer irrigated. The drought stress stimulates the spore production of the VAMF.

- One week after termination of irrigation, the plants are cut off and the pots with the roots are kept dry for another two weeks (B). After this period the roots are removed from the substrate.

- The substrate is spread out in a thin layer and air-dried rapidly (C). The dry inoculum can be stored under cool and dry conditions for more than a year.

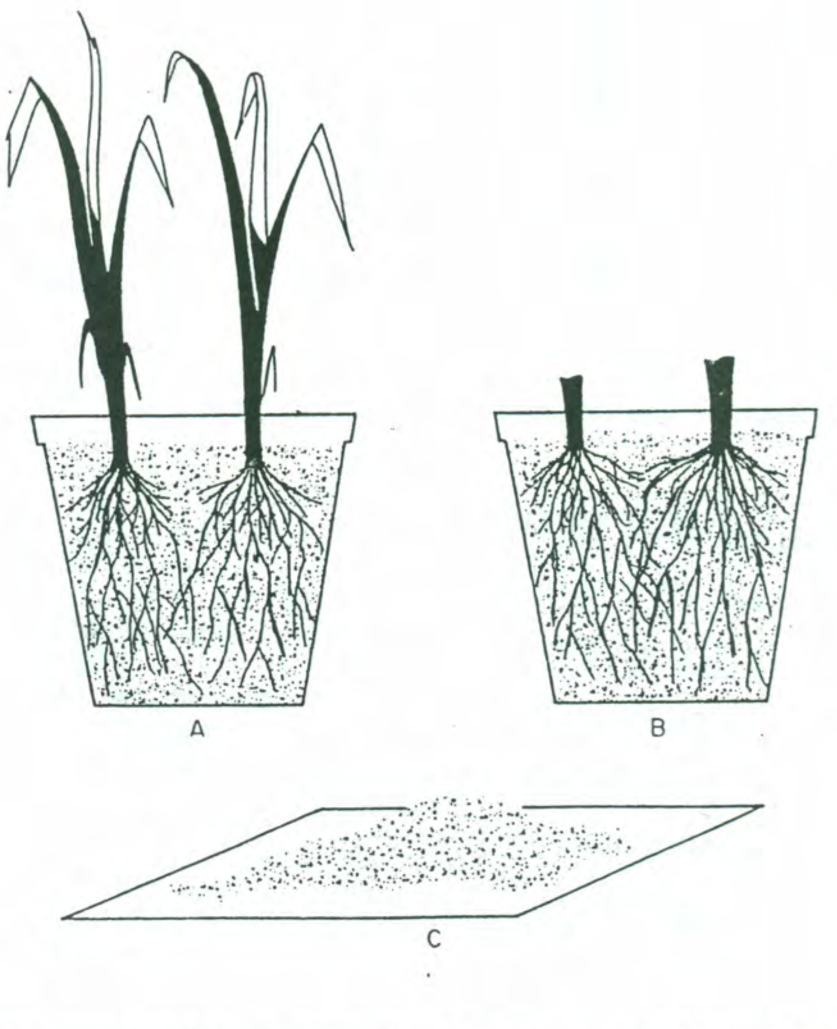

Fig. 3: Mass production of inoculum (Feldmann & Idczak 1992). See text for details.

Alternatively to the procedure of inoculum production described above, the multiplication of the VAMF can be carried out directly in the field as well (in-situ production). Feldmann (1991) showed that the inoculation of host plants (e.g. corn) with VAMF in the field at the time of sowing or planting results in an increase of the number of VAMF spores from 4 to 57 spores per gram of soil after two months.

Application of VAMF inoculum

The inoculation of plants with mycorrhizal fungi can be performed in different ways:

- The fungal inoculum can be mixed homogeneously with the substrate in which the plants are grown.
- A concentrated layer of the inoculum can be placed below the seeds or the plant roots.

The method of inoculuation and the amount of the applied inoculum (0; 0.2; 1; 5 and 10% Vol.) determine the development of the mycorrhizal association (fig. 4).

The highest degree of root colonization of rubber tree seedlings (Hevea spec.) is achieved by use of more than 1% (v/v) of inoculum in the substrate. The homogeneous distribution of the inoculum finally leads to a higher degree of root colonization compared to the method of "concentrated application", although a higher percentage of root colonization is achieved with the latter method during the early stages of the development of the symbiosis. This is probably due to the fact that in the case of a "concentrated application", the roots of a seedling have contact to a large number of infection units when growing through the inoculum layer. At this moment a heavy infection of the root system occurrs. After the roots have passed the inoculum layer no further infection units of VAMF are present. The fungus has to spread over the whole root system from the site of the primary penetration points. In case of a homogeneous distribution of the fungal inoculum, new infections of the roots by the fungus are possible even after a longer time of the development of the root system. For this reason we recommend applying the inoculum in the form of a homogeneous mixture, but the "concentrated application" has also been proved to be successful in the field.

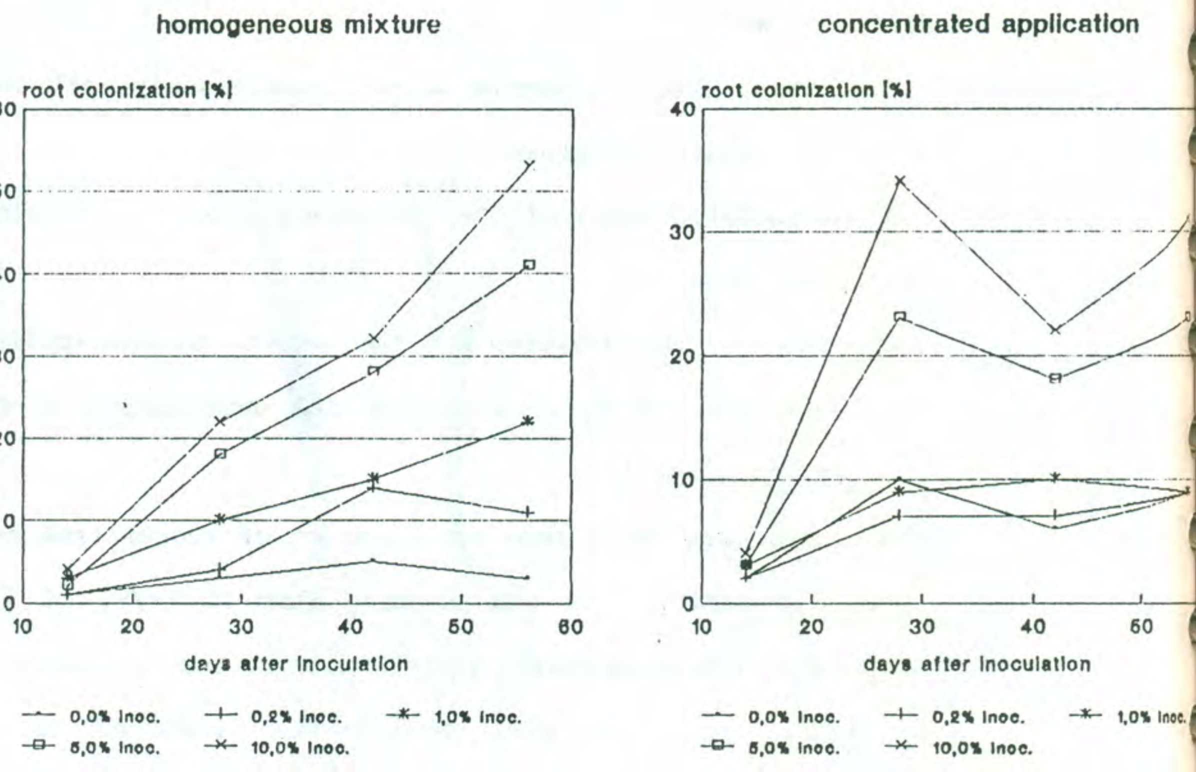

Fig. 4: Root colonization by VAMF in dependency of the method of application and the amount of the inoculum applied.

The use of VAMF in mixed cropping systems

The introduction of VAMF in agricultural systems as a management factor is simple. If the isolation, selection and the production of the start inoculum are carried out by official institutes or specialized companies, the farmer has to produce the inoculum on a large scale, which is best done in containers with sand or sterilized porous soil. The produced inoculum is then used for the inoculation of plants in the nursery by mixing it homogeneously with the substrate. In this way the plants will already be mycorrhizal when they are transplanted into the field. This will be of benefit to the plants during the first critical phase of adaptation to the new environmental conditions.

If a farmer wants to inoculate non-mycorrhizal perennial plants which are already planted into the field, he can do so by use of "nurse plants". This means that he should sow or plant crops which are often used in inoculum production (e.g. corn) close to the perennial plants and inoculate them with VAMF. The "nurse plants" will multiply the VAMF inoculum in the soil and the roots of these mycorrhizal plants will grow close to the roots of the perennial plants and thus inoculate them. If the management in the plantation takes account of the requirements of the VAMF (less fertilizer, less pestizides, more secondary vegetation), the fungi can establish themselves in the field.

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PREPARO E APLICACAO DE FUNGOS MICORRIZICOS SELECIONADOS PARA POLYCULTURAS

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Introducao

- A maioria das plantas uteis das regioes tropicais sao altamente dependentes dos fungos micorrizicos vesiculo arbusculares (FMVA)
- Em sistemas agricultorios uma deficiencia alta dos simbiontes foi observado que implicou usar FMVA como agentes biologicos para meliorar a saude das plantas.
- Na Manaus, AM, uma polycultura das plantas uteis perennes foi installado no que o manejo respeita as necessidades dos fungos (menos adubo, menos pesticidas, mais plantas secundarias...). A polycultura foi installado numa area degradada e abandonada. Na fase da implantacao FMVA selecionadas foram usadas para aumentar o "fitness ecologico" das plantas.
- Nesta presentacao os methodos da producao e aplicacao do inoculo para este projeto sao mostrados.

PASSO I

Como ganhar isolados dos FMVA?

- FMVA sao usados como
  - Isolados puros (originados de somente um esporo singulo do FMVA) (1)
  - Misturas dos isolados puros conhecidos
  - Misturas nao conhecidas com um efeito provado e estavel (2)

PASSO II

A procedura da selecao

- A micorriza tem efeitos especificos:

  Existe uma especifidade em relacao
  - ao hospite
  - a natura do efeito
  - tambem o efeito depende do meio ambiente
- Por isso e necessario selecionar os FMVA mais efectivos

Efeito de diversos FMVA no Eupatorium odoratum

Definir qual efeito a micorriza deve mostrar
Definir os fatores abioticos da selecao (incluido substrato, adubacao, pH ...)
Aprovar infectividade do inoculo com ...

Testar na casa de vegetacao se sua planta e micotrofa: os FMVA podem colonizar as raizes?
plantas colonizadas creacem melior doque sem micorriza?

Se sua planta e micotrofa, analiser o grao da dependencia. Ela e obligatamente ou facultativamente micotrofa?
Este analise e feito num experimento com div. nivels de adubos.

Definir os fatores abioticos da selecao de novo respeitando grao da dependencia, condicoes na area do uso e necessidades do manejo.
Comparar os FMVA ao efeito desejado.

PASSO III

Producao do inoculo primario

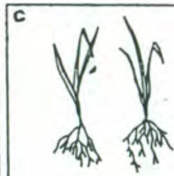
A

Enxer vasos com areia (2/3 do volume)
Collocar FMVA (solo, esporos...) em cima.
Semear sementes de uma planta micotrofa. (milho, mamao...).
Cobrir de areia.
Regar baixo da capacidade do campo.
Aduber pouco (< 60ppm P).

B

Deixar as plantas creacer por 3-4 semanas ate as raizes sao colonizadas intensivamente.
Controler a colonizacao com um microscopo.
Nao usar pestizidas, ou somente aquelas que nao tem inconveniente.

C



Quando as raizes sao bem colonizadas, isoler as plantas cada um por si.
Laver as raizes.
As vezes e necessario esterilizar a superficie das raizes (ethanolo...).
Pode fazer neste passo.

D

As plantas sao usadas depois para a multiplicacao dos fungos de grande escala (Passo IV).

Fonte:
Feldmann, F. & Idczak, E.: Inoculum production of VAM-fungi for use in tropical nurseries. Methods in Microbiology (24), 339-357, 1992

PASSO IV
Producao da grande escala

A

As plantas de passo III sao transferidas para vasos grandes ou caixas de madeira. Depois 3-4 meses as raizes devem enxer todo volume do vaso ou da caixa. Neste momento nao regar mais e deixar as plantas secar.

B

Uma semana depois a irrigacao terminou, as plantas sao curtadas. Deixar mais duas semanas secar. Tirar as raizes secas.

C

Secar o substrato numa camada fina no ar (1 semana). Armazenar o inoculo num lugar seco e com a temperatura entre 16-25°C. A armazenagem e possivel por mais de um ano.

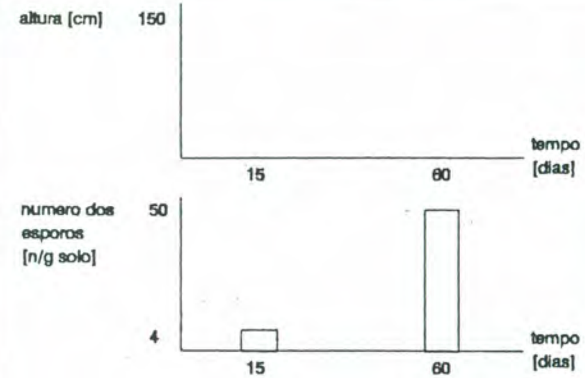
Inoculo de argila expandida

D

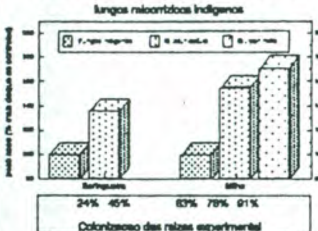
Em nossos experimentos com plantas perenes usamos um inoculo da argila expandida (metodo de Dehne e Backhaus, 1986). Argila expandida e misturavel muito simples com outros substratos, nao e muito pesado e nao favorece patogenos. Tambem usamos areia e terico para a multiplicacao dos fungos.

VARIANTE DE PASSO IV
In-situ producao do inoculo

Uma inoculacao das plantas dependentes no campo resulta numa aumenta do numero dos esporos dos FMVA: por exemplo MILHO



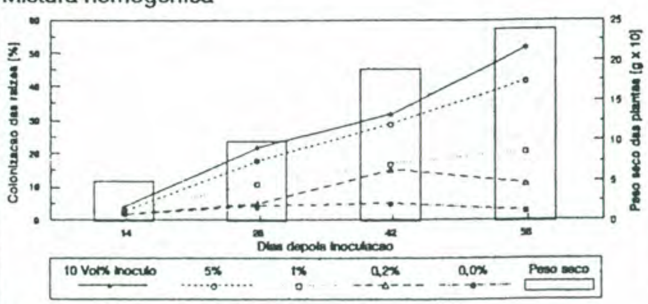
Producao no campo com Milho



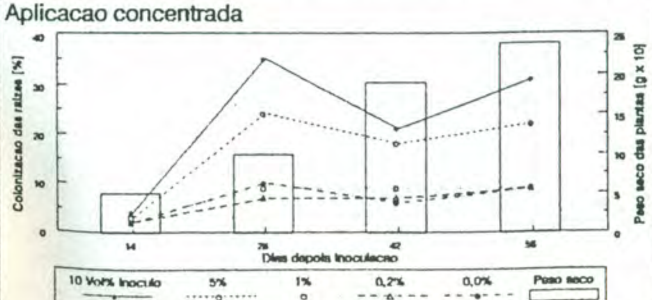
Fungos micorrizicos introduzidos competem com successo com FMVA indigenos e sao mais efectivos.

METODOS DA APLICACAO

Mistura homogenica



Aplicacao concentrada



Aplicacao concentrada

O successo da inoculacao depende
- do metodo da aplicacao
- da quantidade do inoculo

Observamos o melior colonizacao com mais de 1%Vol inoculo e a forma da aplicacao "mistura homogenica" (feito em vasos).

No campo uma "aplicacao concentrada" debaixo de semente e bem sucedido (veja foto.).

Uso na polycultura

Incluir o uso da micorriza nas sistemas da producao agricultoria e simple:

- **Se os primeiros 3 passos sao feitos por Institutos oficiais ou empresas especiais o produtor tem que produzir inoculo na grande escala, melior em caixas de madeira com areia ou solo (terico) esterilizado. A esterilizacao pode ser feito com brometo de metilo ou solarizacao.**
- **Depois o inoculo e misturado homogenico com o substrato no viveiro. Entao as plantas plantadas fora no campo ja estao micorrizadas. A micorriza vai favorecer a fase initial da planta no campo.**
- **No caso que um produtor quer inocular plantas perenes ja plantadas sem micorrizacao ele pode inocular plantas dependentes como milho ou mandioca semeando ou plantando-as perto das plantas perenes ("nurse plants"). As raizes das nurse plants vao crescer para as raizes das plantas perenes e inocular-as.**
- **Se o manejo na plantacao e adaptada, as FMVA podem estabilizar-se (menos adubo, menos pesticidas, mais plantas secundarias).**

plantas secund. substituem a estabilizacao dos simbiontes

Appendix 4

Kubrom, I. (1993): Isolierung und Charakterisierung der Rhizosphärenbakterien von Hevea brasiliensis und Theobroma grandiflorum;
Diplomarbeit, Universität Hamburg, April, 1993
here: Summary

Bakterien der Rhizosphäre

von

Nutzpflanzen

Diplomarbeit

vorgelegt von

Iyob Kubrom

aus

Asmara/Eritrea

Hamburg 1993

1. EINLEITUNG

Der Boden beherbergt eine große Anzahl von Mikroben, die für die Zersetzung organischer Stoffe, für den Aufbau der für die Biomasse notwendigen Mineralbausteine sowie für die Mobilisierung von Nährstoffen verantwortlich sind. Sie spielen damit in der Natur eine wichtige Rolle.
In der nahen Umgebung von Pflanzenwurzeln bildet sich eine Lebensgemeinschaft, wodurch der Bodenbereich hier eine höhere Populationsdichte von Mikroben aufweist als in dem von den Wurzeln entfernten Bereich. Der Teil des Bodens, der mit Pflanzenwurzeln durchzogen ist, wird Rhizosphäre genannt (Campell, 1980). Im Rhizosphärenbereich wurden bis zu 10^{10} Mikroorganismen pro cm^3 gemessen. Im wurzelfreien Boden des gleichen Systems liegt die Mikrobenzahl bei 10^9 (Fritsche, 1990).
Neben einer sehr hohen Anzahl von Bakterien, sind in geringerer Konzentration Pilze und auch Aktinomyceten in der Rhizosphäre anzutreffen. Die Aktinomyceten verdienen insofern eine besondere Beachtung, da viele von ihnen Antibiotika produzieren und dadurch antagonistisch gegen Pilze und Bakterien wirken können.

Der R:S-Wert (root:soil), der das Verhältnis zwischen der Anzahl von Mikroorganismen in der Rhizosphäre zu der Anzahl von Mikroorganismen im entfernten Boden angibt, schwankt oft zwischen 5 und 20 (Rovira und Davey, 1974). Daß sich sehr viele Bakterien in der Rhizosphäre befinden, kann seine Ursache darin haben, daß Exudate und Pflanzenreste von den Bakterien aufgenommen werden. Außerdem werden die Rhizosphärenbakterien durch die von der Pflanze abgesonderten Exudate (Verbindungen wie Kohlenhydrate, Aminosäuren, Amide, Karbonsäure, Vitamine) in ihrem Wachstum stimuliert.
Betrachtet man anstelle von taxonomischen Gruppierungen Gruppen mit ähnlichen Nährstoffbedürfnissen, dann findet

man bei denjenigen Organismen die größte Zunahme, die relativ komplexe Anforderungen stellen, insbesondere bezüglich der Aminosäuren. Dies spiegelt sich im häufigen Auftreten von Aminosäuren in den Ausscheidungen von Pflanzen wieder (Campell, 1980).

In der Rhizosphäre werden selektiv gram-negative Stäbchen, sporenlose Bakterien (Agrobacterium, Corynebacterium, Pseudomonas, Rhizobium) und viele zum Stickstoffkreislauf gehörige Bakterien in ihrem Wachstum stimuliert. Bei Zugabe von Aminosäuren und Glucose in den Boden zeigen die Bakterien eine höhere Wachstumsrate sowie eine größere physiologische Aktivität, was zur Ansäuerung der Dextrose-Nährlösung führt. Viele Rhizosphärenbakterien sind zudem gegen einige Antibiotika resistent.
Der Nähr-stoffanspruch von Mikroorganismen-Isolaten ist einer der entscheidenden Faktoren für die Differenzierung in Mikroorganismen der Rhizosphäre und den Mikroorganismen, die im wurzelfreien Boden leben. Eine große Anzahl von Bakterien aus Rhizosphärenisolaten benötigen mehr Amino-säuren für ihr maximales Wachstum als solche im wurzel-freiem Boden vorhanden sind (Lochhead und Rouatt, 1958).
Daneben ist die physiologische Aktivität ein weiterer wichtiger Faktor zur Unterscheidung der Mikrooganismen. Die durchschnittliche Sauerstoffverwertung aus Saccharose, Glucose, Acetat, Succinat und Alanin ist durch Rhizosphärenisolate größer als durch die Bodenisolate (Zygallo und Katznelson, 1957).
Die Zusammensetzung der Bakteriengruppe in der Rhizosphäre ist unter anderem von der jeweiligen Pflanzenart abhängig (Krasil'nikov, 1958).
Aufgrund ihrer vielfältigen Enzymaktivitäten sind die Bakterien erheblich am Stoffkreislauf im Boden beteiligt, wie z.B. an der Luftstickstoffbindung, an der Unterdrückung von verschiedenen pflanzenpathogenen Organismen, am Ab- und Umbau organischer Stoffe, am Abbau von

Agrochemikalien, an der Bildung und Stabilisierung der Bodenstruktur sowie an der Bereitstellung von Wirkstoffen (Antibiotika, keimungs- und wachstumsfördernde Substanzen wie Giberelline, Vitamine u.a). Durch die Erschließung von Nähr- und Wirkstoffen wie auch durch phytosanitäre Wirkungen der Rhizosphärenmikroorganismen kann die Pflanze in ihrer Entwicklung gefördert werden. Der Gebrauch dieser natürlichen Ressourcen kann die Beschränkung der Schadstoffbelastung von Boden- und Grundwasser und der Umweltbelastung bei der Produktion von Agrochemikalien ermöglichen (Höflich, 1992).
Eine wichtige Rolle in der Bodenmikrobiologie ist der Beitrag der Mikroorganismen zur N_2-Fixierung, die P-Mobilisierung sowie die Verbesserung des Schutzes vor bodenbürtigen Schadenserregern. Um eine ressourcensparende Ertragssteigerung und -Sicherung zu erzielen, wird gezielt mit der Selektion und Inokulation von Mikrooganismen gearbeitet.

Die Pflanzen Hevea brasiliensis MUELL ARG und Theobroma grandiflorum L, aus deren Rhizosphären die Proben für die vorliegenden Arbeit stammen, sind zwei wichtige tropische Kulturpflanzen im Amazonasgebiet (Brasilien). Es existieren keine Daten über Rhizosphärenbakterien der zwei oben genannten tropischen Nutzpflanzen.

Ziel dieser Arbeit ist :
- Die Isolierung der Rhizosphärenbakterien sowie der Bakterien aus dem pflanzennahen, nicht durchwurzelten Boden der tropischen Nutzpflanzen Theobroma grandiflorum und Hevea brasiliensis. In dieser Arbeit wurde der Unterschied zwischen Rhizosphärenbakterien und Bakterien aus dem wurzelentfernten Boden ermittelt. Pilze aus der Rhizosphäre wurden nicht untersucht.
- Die Charakterisierung sowie taxonomische Anordnung der Bakterienisolate wird durchgeführt.

6. Zusammenfassung

Aus einer Bodenprobe der Rhizosphäre zweier tropischer Nutzflanzen, Theobroma grandiflorum und Hevea brasiliensis, die aus Manaus in Brasilien stammen, wurden Bakterien isoliert mit dem Ziel, sie zu identifizieren. Anschließend wurden die einzelnen Baktrienisolate auf das Pflanzenwachstum untersucht.
Zur Identifizierung der einzelnen Bakterienisolate wurden morphologische, physiologische und biochemische Tests durchgeführt. Mit Hilfe von Computern wurden 9 verschiedene Bakterienstämme ermittelt.
Eine unterschiedliche Anzahl von Bakterien im Rhizosphärenbereich und im wurzelfreien Boden konnte durch Plattierung und MPN (Most Probable Number)-Methode gezeigt werden.
Von 9 Bakterienisolaten unterschiedlicher Gattungen aus der Rhizosphäre von Theobroma grandiflorum und Hevea brasiliensis, die in die Testpflanze Petroselinum Crispum inokuliert wurden, bewirkte im Kolbenversuch (steriler Ansatz) ein Pseudomonas-Stamm reproduzierbare Wachstumsstimulierungen in der Jugendentwicklung der Pflanze.
Gefördert wurde die Sproß- und Wurzelfrischmasse-entwicklung, sowie die Sproß- bzw. Wurzellänge.

PRESENTATIONS OF THE SHIFT-PROJECT ON NATIONAL AND INTERNATIONAL SCIENTIFIC MEETINGS AND IN THE TRAINING PROGRAM OF THE UNIVERSITY OF HAMBURG

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Introduction

The bilateral, Brasilian/German project "Recultivation..." between the CPAA, Manaus, and the IAngBot, Hamburg, is not only of high importance for the development of new, practicable strategies to overcome the problems of environmental destruction and demand of productive agricultural areas in the humid tropics of Amazonia, but also influences the research and training activities in both engaged institutions. The running project functions as a cristallization point for the development of new hypothesis and ideas which could lateron result in additional subprojects on special topics based on results of the pilot project and carried out as further detailed field studies on the experimental area in Manaus.

For a fruitful ongoing of the line of research within the project a lot of talks, lectures and poster presentations of the current state of the project are necessary to discuss problems and scientific questions with an interdisziplinary auditory, especially with other participants of the SHIFT-program between the Brasilian IBAMA and the German BMFT.

As well the project "Recultivation..." gives an important impulse for the education program of the Department of Biology of Useful Plants, IAngBot, University of Hamburg.

In this contribution an overview about the presentations of the current project on scientific meetings and in the University of Hamburg is given. The catalogue of presentations does not include the list of scientific publications.

Catalogue of presentations

A. Presentations on national and international meetings

- 6. Jahrestagung der Deutschen Gesellschaft für Tropenökologie "Mensch und tropische Umwelt - Partner und Zerstörer", 18.-21.02.93

For the first time after the plantation in Manaus was installed the project was presented to the community of tropic ecologists in Berlin (Feldmann & Lieberei, 1993a, 1993b). In an oral contribution the theoretical basis of the project and the state of realization was outlined (Feldmann & Lieberei, 1993a).
In the discussion of that contribution the auditory showed great interest in the question, in how far the social background of the Amazonian people was respected and integrated while outlining and carrying out the project. As well the economic reasons for the selection of the chosen useful plant species and the four realized planting systems was discussed intensively.
After the contribution an interview for the Berlin Broadcasting Service RIAS BERLIN was given. The interview was publicated in a short version with the comment that such a planting system using perennial plants for moderate extraction of goods should take part in future prevention systems for the protection of the Amazonian environment.
The importance of interrelationships between social aspects and the current project were pointed out during a poster presentation (Feldmann & Lieberei, 1993b). Fields of discussion were: how does the acceptance of a new planting system will be influenced by the origin of the farmer? Which practices could enhance the acceptance of the planting systems? In how far the outlayed planting system will create changes in the educational structure of the farmers community?

- 1st SHIFT-Workshop in Belem, PA, Brasil, 8.-13.03.93

On the First SHIFT-workshop in Belem participants of all projects of the SHIFT-program reported on the state of their project. The project "Recultivation..." was presented by Lieberei et al. (1993a)

Detailed informations about the results of this workshop can be found in the band of "Reports of the 1st SHIFT-Workshop in Belem, PA, Brasil, 8-13.03.93"

- International Symposium "Manejo e reabilitacao de areas degradadas e florestas secundarias na Amazonia" 18.-22.04.1993, Santarem, Brasil

Several contributions on the symposium "Manejo..." in Santarem dealt with the subject of recultivation of degraded lands with perennial plants like the project "Recultivation..." does (Feldmann et al, 1993c). In a lot of discussions with the auditory of poster presentations it could be seen, that there are a lot of different opinions about the possibility to enhance the productivity of degraded areas and that resulting from that several strategies for the exploration intensity are lined out. The idea of only moderate output of a plantation, not orientated in intensive return but in sustainability about decades was found very rarely.
The importance of soil microbiological factors for the recultivation process of degraded areas was mostly - sometimes agressively ("nonsens!") denied. Only in the case of already knowing something about the possible effects of mycorrhizal fungi on growth and health of plants the interest lead to fruitful discussions. In one case our group was invited to give a methodological introduction into the process of using mycorrhizal fungi in practice.
An important impulse of the symposium for the project "Recultivation..." was the circumstance that most of the oral contributions pointed out the importance of the integration of cattle production into the plant production system. Especially the broad acceptance of the idea to produce the cattle in small corrals feeding them with produced plant material should lead to considerations in how far the project "Recultivation..." could intensify its orientation on that item.
It was interesting that social aspects were thought here -as it was in Berlin- to be the most important alignment for research projects in Amazonia. In a discussion someone said projects should be proved to be practicable or -if not- not to be supported by the Brasilian government. This extreme opinion got a lot of applause.

The experiences made on the symposium in Santarem showed more than others that not only the results measured as return of a planting system will decide if the idea of the project "Recultivation..." will be respected by other research teams or not. It will be

as well or even more important to answer the question why the results are how they are. As well only a practible and profitable methodology for the management of the plantations will be accepted.
But probably the most important thing to enhance the acceptance of the project will be that the presentation of the project is responsibly made by the whole research team, Brasilian and German co-workers together.

- *International Symposium "Tropische Nutzpflanzen", 20.-24.09.1993, Hamburg, FRG*

The symposium in Hamburg gave the possibility to present the project "Recultivation..." to a broad auditory which was especially interested in tropical useful plants. Additionally to that auditory representatives of the German Ministery for Research and Technology visited the symposium. Therefore several presentations of the co-workers of the project were given (oral contributions: Bauch, 1993; Preisinger & Feldmann, 1993; Lieberei et al. 1993b; Moraes, 1993; posters: Feldmann et al, 1993b + 1993c; Idczak & Feldmann, 1993; Junqueira et al., 1993; Lieberei et al., 1993c; Müller et al., 1993; Neves & do C. Canto, 1993; Preisinger & Coelho, 1993; Schmidt et al., 1993; Appendix 1).
The response of the participants of the symposium was without exception positive. Constructive criticism was accentuated to the following questions: how will the produced goods be transported to the marked; is there a manufacturing industry in an acceptable distance to the fields; how can the mycorrhizal technology be introduced to farmers in practice; can the new management practice be called "alternative production" which would mean better prices on the marked of exported goods.

- *Colloquium of the Institute of Tropical Agriculture, 01.11.93, Göttingen, FRG*

One of us (Feldmann) was invited by Prof. Vlek, Göttingen, to speak about the use of mycorrhizal fungi in the project "Recultivation...". Prof. Vlek is envolved in the project "Fallow vegetation..." of the SHIFT-program in Belem. Because of the fact that his department has a long tradition of mycorrhizal management in agroecosystems the discussion of biological aspects of the mycorrhizal introduction in the project

"Recultivation..." was a very important reflection of the soil microbiological aspects of the project. After the talk both sides agreed that further exchanges of experiences would be mutual for both sides.

B. Representation of the project in the educational program of the University of Hamburg

In the Institut für Angewandte Botanik students of Biology are studying Applied Botany. At several points of the educational program aspects of the project are presented since the project "Recultivation..." is going on.

- Seminars (Feldmann):
    - Plant-Microbe-Interactions I-III: the rhizosphere of tropical plants; fungal and bacterial symbiosis; ecological importance of mycorrhizal fungi: possibility to use them in tropical agriculture
    - The role of mycorrhizal fungi in tropical ecosystems
    - Influence of mycorrhizal fungi to the Rubber Tree Leaf Blight disease

- Practica (including experiments on tropical useful plants):
    - Applied Plant Physiology (Feldmann)
    - Ecophysiology of useful plants (Lieberei and Feldmann)
    - Secondary plant products (Lieberei)

- Lectures (Lieberei):
    - World trade plants

- Diplom-Thesis (Lieberei):
    - I. Kubrom: Isolation and identification of rhizosphere bacteria of Theobroma grandiflorum and Hevea brasiliensis
    - C. Reisdorff: Parameters of fruit ripening of tropical useful plants

- Exhibitions (Feldmann and Lieberei):
    - Recultivation of abandoned areas in Amazonia (Staatliches Museum für Angewandte Botanik, Hamburg)

- Recultivation of abandoned areas in Amazonia (Ministry for Research and Technology, Bonn, planned for 1994)

C. Further presentations

- Description of the project in the internal journal of the University of Hamburg (Appendix 2)
- Interview with "Uni Presse HH"
- Description of the project in a brochure of the Ministry for Research and Technology to inform the Parliament of Germany about tropical activities of German institutions (Appendix 2)

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Appendices:

Appendix 1

Mycorrhizal status of an abandoned rubber tree plantation after slashing and burning

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The importance of va-mycorrhizal fungi for the "ecological fitness" of their host plants is well known. In recultivation programs of abandoned monocultural plantations special attention must be paid to these symbiotical fungi as the mycorrhizal potential of the soil might be very low.

In case of the abandoned rubber tree plantation in the Amazon region the quantity of va-mycorrhizal spores ranges between 2 - 16 spores per cm^3 soil. However, the determination of the most probable number of infection units by means of a standardized MPN-test reveals that the infection potential six months after slashing and burning is zero. This indicates that the spores are dead or that they are in a resting state. Even nine months after slashing and burning of the abandoned rubber tree plantation the roots of different plant species of the spontaneous secondary vegetation are only colonized to a very low extent which might be due to the fact that these plants are no suitable host plants for the va-mycorrhizal fungi - grown in the field show a higher degree of root colonization.

Thus the cultivation of corn might serve as a tool to increase the number of mycorrhizal propagules in the process of recultivation. Another possibility to improve the mycorrhizal status in the field is the inoculation of the plants with va-mycorrhizal plants for plantation.

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Native Fruit Species of Economical Potential from the Brazilian Amazônia

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Though many native amazonian fruit species have been described as having potential for cultivation, due to constraints as low yield, difficulty of cultivation, and, more frequently, taste peculiarities, most of them remain with only relative local importance. Some species mot presenting these constraints are being progressively more widely cultivated and more consumed in the amazon region and southern Brazilian states and may perhaps have acceptance in foreign countries.

These are:
1) Cupuaçu (*Theobroma grandiflorum*)
2) Araçá-boi (*Eugenia stiptata*)
3) Bacuri (*Platonia insignis*)
4) Muruci (*Byrsonima sericea*)

Only *Theobroma grandiflorum* is object of research at EMBRAPA. Other species such as the *Rubiaceae* Purui (*Allibertia sorbilis, Thielodora verticilata, Luroya macrophylla*) and Genipapo (*Genipa americana*) also deserve attention. A summary of botany, geographic distribution, cultivation technique, agronomical and economical problems is presented for each species.

Characteristics and utilization of importent tropical timber species

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Density, elastomechanical properties, accessory compounds and heartwood fomation determine to a great extent quality and utilization of a wood species. On account of the constant demand for tropical wood a detailed knowledge on these properties is needed in order to utilize the various timbers properly. After harvesting losses in quality and quantity due to unqualified storage and downstream processing are quite common. For three West African timbers new results on certain characteristics are presented. Prudent application of this knowledge can contribute to saving valuable biomass and preventing its improper use.

Pycnantus angolensis (Exell) is esteemed for its bright cream-coloured wood, but suffers severely from discolouration during storage and drying.The discolouration is caused by physiological activities of bacteria which generate coloured accessory compounds from precursors natural to the wood. Such bacterial activities can be impeded by prophylactic treatment.

Terminalia superba (Engl.& Diels), a very common species on the European market frequently develops a brown-coloured false heartwood, which is not accepted for many uses such as face veneers. The formation of false heartwood in Terminalia superba is caused by severe wounds, an important finding with regard to exploitation practices in the forest.

Lophira alata (Banks ex Gaertn.) is in great demand as an exterior construction timber for its high natural durability and mechanical strength. Because of unsufficient visible differences between sapwood and the durable heartwood, sapwood containing pieces are frequently used for structural purposes, which will then lead to premature failure due to biological degradation. Therefore characteristics of sapwood senescence and heartwood were studied in order to supply timber users with valid criteria for differentiation.

Integrierte Anbaumaßnahmen für tropische Nutzpflanzen am Beispiel des Kautschukbaums (Hevea species).

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Hevea brasiliensis (Willd. ex Adr. de Juss) Muell. Arg. ist weltweit die einzige wirtschaftlich bedeutende Rohstoffquelle für Naturkautschuk. H. brasiliensis stammt aus dem Amazonasbecken, aber wirtschaftlich lohnender Plantagenanbau findet sich nur außerhalb Südamerikas, vor allem in Südostasien. Die Biologie dieser sehr jungen Kulturpflanze sowie ein hochangepaßter Schadpilz (Microcyclus ulei [P.Henn.]Arx.) haben alle Kultivierungsmaßnahmen für Kautschukbäume in Südamerika bislang erfolglos enden lassen.

Von 1972 bis 1986 wurden in Brasilien im Rahmen national geförderter Maßnahmen Kautschukplantagen in Amazonien angelegt und parallel dazu, gefördert durch Maßnahmen der Weltbank, begleitende Forschungsprojekte durchgeführt. Pflanzenbauliche, biologisch-systematische und phytopathologische Projekte waren mit Züchtungsprojekten kombiniert. Weiterhin fand die Analyse der Rassenstruktur des Haupschaderregers, des Schadpilzes Microcyclus ulei, statt, biochemische Resistenzfaktoren des Kautschukbaumes wurden erfaßt und erste Untersuchungen zur biologischen Kontrolle von M. ulei wurden erarbeitet. Die Kombination der nunmehr vorliegenden Befunde erlaubt, ein erfolgversprechendes Konzept zum Anbau von Kautschukbäumen in Südamerika zu erstellen.

Erprobung von Mischkultursystemen auf einem Terra-Firme-Standort Amazoniens

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Auf einer aufgelassenen Kautschukplantage der EMBRAPA, 28 km nördlich von Manaus (Amazonas) gelegen, wurde in einem brasilianisch-deutschen Gemeinschaftsprojekt (im Rahmen des SHIFT-Förderprogramms des BMFT) eine Mischkultur-Versuchsplantage angelegt. Die Fläche ist ein Beispiel für einen Terra-Firme-Standort (Bodentyp: gelber Latosol), dessen langfristige Nutzung durch ausdauernde Kulturen bisher große Probleme bereitet. Mit der Plantage wird der Versuch unternommen, derartige Brachen unter Einsatz alternativer Anbaukonzepte wieder zu nutzen, anstatt neue Primärwaldflächen für die Plantagenwirtschaft zu roden.

Mit der 19 ha großen Plantage werden in verschiedenen Testvarianten vor allem drei Möglichkeiten erprobt, um eine langfristige, erfolgreiche landwirtschaftliche Nutzung der Standorte zu erreichen:

1. Inokulation der Jungpflanzen mit Mykorrhizapilz-Sporen;
2. Erprobung unterschiedlicher Mischkultursysteme (u.a. Anbau von Kautschuk - *Hevea sp.*, Cupuaçu - *Theobroma grandiflorum*, Urucum - *Bixa orellana*, Kokos - *Cocos nucifera*, Zitrus - *Citrus sinensis* in verschiedenen Artenzusammensetzungen sowie der drei heimischen Waldbaumarten Paricá - *Schizolobium amazonicum*, Mogno - *Swietenia macrophylla* und Andiroba - *Carapa guianensis* für die Holznutzung);
3. Versuche mit dem Unterwuchs an spontaner Vegetation zwischen bzw. unter den Nutzpflanzen.

In dem Vortrag werden die dem Projekt zugrunde liegenden Arbeitshypothesen, die Versuchsanlage sowie laufende und geplante Untersuchungen vorgestellt.

Parameters of Fruit Ripening for Mangoes cv."Sensation" (*Mangifera indica* L.)

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International trade in mangoes is currently restricted because of unpredictable quality and often high market losses, as only limited information is available concerning their postharvest physiology and biochemistry. Research is required to determine mango fruit quality caracteristics in order to allow a later investigation of the effects of various storage and ripening techniques on the development of these parameters. The topic of this experiment was to evaluate characteristic postharvest changes of mangoes in order of their significance as ripening parameters.

Air-freighted shipments of firm mangoes of the cultivar "Sensation", produced in Kenia, were obtained from an importing firm in Hamburg. Fruits were ripened at 20 °C and 70 % relative humidity. Daily the respiration rates of 6 mangoes were individually measured by infra-red gas analysis. At intervals of 2 days analyses of biochemical and physical characteristics were carried out in duplicate on three fruits.

The fruits reached the eating ripe stage between the 12th and 14th day after harvest. Thereafter the acceptability decreased on account of shrivelling skin and developing anthracnose.

From the commencement of the measurements a respiratory rise was recorded which led to the climacteric maximum between the 7th and 10th day after harvest. Subsequently the respiratory activity declined. After the 14th day from harvest the respiration courses were different between individual mangoes.

Ripening was associated with a loss in firmness accompanied by a reduction in the content of alcohol insoluble solids. Acidity loss was indicated by decreasing titratable acidity and increasing pH values, which were, however, not directly correlated. The starch level reduced drastically to a minimum below the detection limit at the ripe stage. Sugar accumulation was maximum at approximately the time of the climacteric peak in respiration and sucrose was predominant with 40 % of the dry matter of ripe fruits. The glucose level initially increased slightly and then fell to a minimum as fruits reached ripeness. The refractive index of the fruit sap attended to rise, but irregularly. The carotene content of the fruit pulp rose continously from the 8th to 16th day after harvest consistently with the development of orange colour. In the context of ripening events no importance could be attributed to the loss in peel chlorophyll.

The respiratory climacteric marks the irreversible onset of the final ripening processes. Thus, storage techniques must extend the period between harvest and climacteric respiration. An efficient treatment would be indicated by a retardation of the starch degradation and the prevention of a respiratory rise. The additional parameters appear necessary to ensure balanced ripening following storage.

C 14

Recultivation of degraded, fallow lying monocultural areas with equilibrated polycultures under special respect to soil microbiological factors

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Degraded fallow areas of primarily monocultural plantations will be transferred into a locally-adapted form of utilization under special consideration of soil microbiological factors (fungal and bacterial symbionts). In accordance with the heterogeneity of natural plant communities, polycultures of several perennial and annual ecologically adapted useful plants are installed. During the installation phase mycorrhizal fungi are introduced as important biological factors to optimize the ecological fitness of the plant material. After the implantation of the polyculture the spontaneous secondary vegetation is managed carefully to reach to a benefitial jointly growth of the secondary vegetation with the useful plants. In this type of naturally enriched polyculture special regard is paid to a careful use of pesticides and fertilizers in order to come to a plant production system with low input and sustaining medium output. Low input systems with a mixture of annual and perennial plants result in an ecologically and economically equilibrated situation for small scale producers.
In this contribution the organization of a multidisziplinary project between Brasilian and German institutions is demonstrated as well as the results of the installation phase of the project.

D 22

Recultivation of abandoned monoculture areas in Amazonia: Functional traits of the spontaneous vegetation in an experimental polyculture plantation

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On a terra firme site near Manaus, Amazonia an experiment in recultivating a fallow rubber plantation of 19 ha by establishing mixed plantations of selected crops, mainly trees, is carried out. In order to achieve sustainability, different crop combinations and different strategies for management of the spontaneous vegetation will be tested.

On the one hand, the spontaneous vegetation which regenerates or colonizes the space between the plantation crops can constitute competition for the crops (light, nutrients, space), in which case it must be suppressed. On the other hand the wild vegetation can be an important store of nutrients, which become available to the crops after dieback and mineralization of the biomass. Whether these two opposed processes can be optimized in favour of the crops by appropriate control of the wild vegetation, is a question that is to be examined.

First steps of the work were a description of the vegetation which dominated the area before planting and the detection of structural traits of the wild plant species involved and their spatial distribution. The vegetation pattern depends on the pre-use of the area and on the type and extent of past disturbance respectively. An accurate description of the spontaneous vegetation is important for the understanding of successional processes which will take place in the polyculture plantation due to different types of management. The description will be given by means of the floristic composition, the growth form structure and strategy types.

D 23, 24

Economic potential of useful plants for the use in sustainable tropical polycultures in Amazonia

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The ecological conditions of the humid tropics of Amazonia bear the necessity to design mixed cultivation systems of several useful plant species which have to be ecologically adapted and have to have an economical potential which guaranties a sustainable stability of the economical situation of low scale producers.
In the near of Manaus, Brasil, recently a polyculture system is being implanted which includes more than 10 perennial and four annual or biannual plant species. Some of them are still relatively unknown in European countries. All of them are shown on photographs and their economic potential described.
In detail one can find: Hevea spp. (Euphorbiaceae), rubber production, timber; Theobroma grandiflorum (Sterculiceae), pulpa for juice, icecream, desserts, seeds for chocolate; Bactris gassipaes (Arecaceae), fruits, palmito, leaves (fodder) food colourings, weaving material; Bertholecia excelsa (Lecythidaceae), nuts, timber; Bixa orellana (Bixaceae), dyestuffs, sunscreens; Cocos nucifera (Arecaceae), oil, copra, coconut milk, oil cake, weaving material, fibres, timber, particle board; Schizolobium amazonicum (Caesalpiniaceae), timber, charcoal; Swietenia macrophylla (Meliaceae), timber; Carapa guianensis (Meliaceae), timber, oil; Carica papaya (caricaceae), fruits, papain, carpain, feeding stuffs; Manihot esculenta (Euphorbiaceae), starch, vegetables; Vigna sinensis (Fabaceae), green fodder, vegetables; Zea mays (Poaceae), Starch, edible oil, feeding stuffs; Pueraria phaseoloides (Fabaceae), cover plant, green manure. Additionally to these ecologically adapted plant species the exotic Citrus sinensis (Rutaceae), fruit, pectin, is planted.
The criteria for the plant selection included several ecological and practical aspects of the plant management but as well the following: The products must be accepted by the people of the Amazon region. The produced goods must have a commercial value and must have the suitability to being transported.

D 25

The environmental changes during field preparation in Amazonas require an ecologically adapted agricultural production system to reach economical stability

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The slashing and burning during the initial phase of the Amazonian field preparation procedure destroys the primeval rainforest vegetation. This destruction followed by pedological degradation and climatic changes guarantees only a short time use and leads to the abandonation of the fields. Abandonation is one of the main reasons for the migration of farmers to new areas with primary vegetation where the cycle starts again.

Only an ecologically adapted agricultural production system can be sustainable and can overcome the problems created by this destructive form of shifting cultivation. A plant production system therefore has to fulfill the following items:

1. An adapted agroecosystem in the Amazon basin has to be a polyculture with the use of mainly indigenous trees.
2. Degraded areas have only very few essential, symbiontic organisms. This occurs at least after several years of fallow, too. In the initial phase of a recultivation effective symbionts, especially mycorrhizal fungi, have to be introduced to the plant production system.
3. A high soil-microbiological stability and high diversity of effective, adapted soil microorganisms is supported by a high number of different host-species. That means that the inclusion of the natural secondary vegetation should have high importance for the stabilization of populations of soil-microorganisms and therefore for the introduced hosts - the utilizable plants -, too.
4. The management of the plantation has to take into account that a high diversity of soil-microorganisms remains in the soil. That means a low input of pesticides and a controlled amount of fertilizers (normally much less than without mycorrhization of the plants).
5. A high diversity of utilizable plants/natural vegetation probably will enhance the disease tolerance of the whole system by changing the microclimate and giving the possibility to establish natural controlling systems.

D 26

Selection of forestry species for the recovery of altered landscape in the Brazilian Amazon

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In developing countries, the inadequate use of natural resources, for different purposes, is causing a gradual elimination of tropical forests, with irreversible loss of the genetic variability of some tree species and soil erosion of extensive areas which are left without use due to the loss of the transient fertility. These areas must be recovered either with homogeneous plantings or agroforestry systems. The Agroforestry Research Center for the Western Amazon (CPAA(/EMBRAPA) started, since July 1991, some experiments with forestry species aiming to select the most promising for use in the reclamation of these areas. The experiments were set up in the experimental field of the CPAA/EMBRAPA, localized in the km 28 of the highway AM 010, in a distrophic Yellow Latossol. This paper presents data of 10 species considered as most promising among the 50 species of the experiments: *Acacia mangium, Eucalyptus urophylla, Sclerolobium paniculatum, Ceiba pentandra, Jacaranda copaia, Péltophorum dubium, Dydimopanax morototoni, Dypterix odorata, Carapa guianensis* and *Enterolobium contertisiliquum*. The species are planted in rows of 10 plants, with 3 m interows and interplant distances, at full sun. Evaluations are carried out every six months in the first year and after that yearly, for index of survival (%), height (m) and diameter at breast height (DBH, in cm). The survival of the species is considered good. The above referred species present the following performance as to height and DBH respectively: 6 months - *A. mangium* (2,30; 1,80), *E. urophylla* (2,05; 1,47),*Sclerolobium paniculatum* (0,25; -), *Ceiba pentandra* (1,92; 1,54), *Jacaranda copaia* (0,44; -), *Peltophorum dubium* (0,61;~), *Dydimopanax morototoni* (0,88; -), *Dypterix odorata* (0,80; -), *Carapa guianensis* (0,63; -) and *Enterolobium contortisiliquum* (1,21; -): at 12 months - *A.mangium* (3,85; 6,07), *E. urophylla* (4,43; 4,28), *Sclerolobium paniculatum* (0,78; -), *Ceiba pentandra* (3,20; 6,73), *Jacaranda copaia* (2,25; 5,48), *Peltophorum dubium* (3,58; 4,51), *Dydimopanax morototoni* (1,55; 2,36), *Dypterix odorata* (1,78; 1,15), *Carapa guianensis* (0,97; -) and *Enterolobium contortisiliquum* (3,17; 5,03).

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Use of VA-mycorrhizal fungi in tropical fruit production on abandoned sites in the Amazon

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In the last decades various attempts have been made to install rubber tree plantations on larger scale in the central region of the Brazilian Amazon. The majority of these plantations has been abandoned because of phytopathological and economical problems. An alternative agricultural use of these sites is difficult to realize. This might be mainly due to the low microbiological activity in the soil which is caused by cultivation techniques and the management of the rubber tree plantations. There is evidence that soil of rubber tree plantations in the Amazon shows a deficiency of VA-mycorrhizal fungi.
The objective of the studies presented is to increase the "ecological fitness" of native fruit species by the inoculation of seedlings with effective VAM-fungal isolates and thus achieve a successful cultivation of these species on the sites mentioned above.

For the experiments the plant species papaya (*Carica papaya*) and maracuja (*Passiflora edulis var. flavicarpa*) were used.

With respect to the VA-mycorrhizal fungi, field soil with indigenous fungi was used as the substrate for seedling production (control plants). The plants of this treatment were compared to plants inoculated with the fungus *Glomus etunicatum D13* and in 1991 to those inoculated with *Glomus etunicatum T6* and inoculated with the native population of a primary forest, too.The plantation into the field was performed as in common praxis.During the whole cultivation period vegetative and generative parameters of the crops were evaluated.

A large increase in dry matter production was observed during the first months, as well as in flower production and fruit harvest, due to inoculation with the fungus *Glomus etunicatum D13*.

Bilanzierung von Bioelementen in tropischen Kulturpflanzen

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In den zurückliegenden Jahren wurden große Flächen des Primärwaldes Amazoniens zerstört und in landwirtschaftliche Nutzflächen umgewandelt, die aufgrund unangepaßter Nutzungsformen, insbesondere Monokultur, nur kurzfristig bewirtschaftbar sind. Mit dem Ziel angepaßte Rekultivierungsmaßnahmen für brachliegende Flächen zu entwickeln, wurde innerhalb eines Kooperationsprojektes der EMBRAPA/Manaus und der Universität Hamburg eine Plantage angelegt, die verschiedene Misch- und Monokulturen beinhaltet.

Im Rahmen dieser vom BMFT-Bonn, der IBAMA und dem CNPq geförderten deutsch-brasilianischen Zusammenarbeit soll unter anderem versucht werden, die Biomasseproduktion der dafür angelegten Plantage in Bezug auf eine nachhaltige Mineralelementversorgung zu bestimmen. Hierfür sollen der Elementgehalt in den einzelnen Pflanzengeweben und die im Boden pflanzenverfügbaren Mineralelemente über die Zeitdauer der Plantage untersucht werden.

Von drei bis sechs Monate alten Jungpflanzen der Arten Castanha-do-Brasil (*Bertholletia exselsia* H.B.K.), Cedro vermelho (*Cedrela odorata*), Cumaru (*Dipterix alata*), Cupuaçu (*Theobroma grandiflorum* (Spreng.) K.Schum.), Dendê (*Elais guianeensis* Jacq.), Mogno (*Swietenia macrophylla* King), Taxi branco (*Sclerobium paniculatum* Vogel) und Urucum (*Bixa orellana* L.) wurde die Biomasse sowie der Elementgehalt innerhalb der verschiedenen Pflanzenorgane bestimmt.

In verschiedenen Pflanzenfraktionen wurden die Elemente Ca, Mg, K, Na, Mn, Fe, Al, Zn, Cu, Pb, B, Co, Sr, Ba, P, S und Si mittels der ICP-OES (Inductively coupled argon plasma with optical-emission-spectrometry)-Methode analysiert.

Da die Gattungen *Theobroma* und *Swietenia* im Hinblick auf die Mineralelementverteilung die größten Besonderheiten aufwiesen, beschränkt sich die Darstellung der Auswertung der bisherigen Befunde auf Cupuaçu (*Theobroma grandiflorum*) und Mogno (*Swietenia macrophylla* King). Dabei wurden von den 16 untersuchten Elementen den Mineralelementen Ca, K, Mg, und Al besondere Bedeutung bei-gemessen.

Der Anteil der Blätter an der Gesamtbiomasse nimmt bei den beiden Pflanzen 50% bzw. bis weit über 70% der Gesamtbiomasse ein.
Der Ca-Gehalt nimmt mit zunehmendem Blattalter zu, was in geringem Maße auch für Mg gilt.
Der K-Gehalt ist bei Cupuaçu vorallem in den Wurzeln, in den älteren Blattgelenken und in den Blattstielen sehr hoch, während sich bei Mogno ein "K-sink" in den jüngsten Blättern abzeichnet.
Insgesamt beträgt bei Cupuaçu der Ca-Anteil 1,32%, der Mg-Anteil 0,24%, der K-Anteil 0,62% und der Al-Anteil 0,29% an der Gesamtbiomasse. Diese Werte sind im Vergleich zu Mogno mit einem Gesamtanteil an Ca von 0,51%, an Mg von 0,10% und K von 0,75%, sowie im Vergleich zu Baumarten der gemäßigten Zone sehr hoch.

D 31

Mycorrhizal situation of native trees in the Brazilian tropical ecosystems Varzea, Igapo, Terra firme and Cerrados

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A lot of tropical trees became useful plants of a great economic potential. Autecological studies on useful plants are one of the most important steps on the way to a plant production system which respects the plants' natural demands. One of the most important biological ecofactors are mycorrhizal fungi. Some of the useful plants are already known to be mycorrhizal, but it is seldom known to which extent the plants depend on the mycorrhizal symbionts. Field studies on the occurrence of the symbiosis under different environmental conditions give a first information about the importance of the symbiosis for the plant at its natural stands.

In this contribution results from a survey on the occurrence of mycorrhizal spores and the root colonization of trees in different tropical ecosystems are demonstrated. The ecosystems Cerrados, Terra firme, Igapo and Varzea mainly differ in the water regime and in the availability of nutrients in the soils. The selected trees were *Hevea spp.* (*H. brasiliensis, H. benthamiana, H. spruceana*) and *Theobroma spp.* (*T. cacao, T. grandiflorum*). It was observed that *Hevea spp.* never occurred without root symbionts, while *Theobroma spp.* sometimes did not form the symbiosis.

In Cerrado soils, introduced *Hevea spp.*, cultivated in very acid soil conditions (pH 4.0), have been observed to be associated with different species of endomycorrhizal fungi, like *Acaulospora rehmii, Acaulospora scrobiculata, Scuttelospora reticulata, Glomus manihotis* and *Glomus occultum*. Though, root colonization by this native mycorrhizal population was very law.

The most intensive root colonization of the rubber tree was observed at water influenced stands (Varzea, Igapo). Theobroma, a genus which occurs mainly on terra firme, showed a lower or no root colonization by mycorrhizal fungi at stands with the best nutritive conditions.

The spore number at every Hevea or Theobroma stand was very heterogeneous, probably due to the sporulation behaviour of different fungal species than to differences in the environmental conditions.

To test the dependency of the trees they were inoculated with a selected isolate of Glomus etunicatum under favourable growing condition for the plants in a greenhouse experiment. Hevea was colonized intensively and the growth was stimulated by the symbiosis.

Theobroma was only slightly colonized and the growth was not significantly stimulated. The conclusion was drawn that both plant genera are mycotroph, but Hevea probably will be recognized in further investigations as obligatley mycotroph, while Theobroma seems to be only facultatively mycotroph.

D 33

Induced polyploidy potential for improving resistance in *Hevea* clones to *Microcyclus ulei*, causal agent of rubber tree leaf blight.

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Components of resistance that reduce the epidemic rate of rubber tree leaf blight, were evaluated on colchicine-induced polyploids (CIP) Hevea clones and on their respective natural diploids ofter inoculation with a virulent *Microcyclus ulei* isolates to the diploid clones. Some plants originated from CIP clones as Fx 985 P1, MDF 180 P1, CNSAM 7704 P1, IAN 873 (IAC 222) and IAN 6158 P1 presented high level of resistance in comparison with their susceptible diploids clones. On the other hand all plants originated from other CIP clones as IAN 717 P1, Fx 4098 P1, Fx 3925 P1, CNSAM 7665 P1 and IAN 6323 P1 were as susceptible as their respective natural diploids. The results indicate the possibilities to use the induced polyploidy for improving resistance in rubber tree clones, against leaf blight.

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Rekultivierung brachliegender Monokulturflächen Amazoniens

R. Lieberei & F. Feldmann

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Deutscher Counterpart: Institut für Angewandte Botanik der Universität Hamburg
Brasilianischer Counterpart: Centro Nacional de Pesquisa Agroflorestal da Amazonia (CPAA, EMBRAPA), Manaus, Brasil

Charakterisierung des Untersuchungsgebietes

Die untersuchten Flächen liegen 30km östlich von Manaus, Amazonas, Brasilien, inmitten ursprünglicher Regenwälder der feuchten Tropen Zentralamazoniens auf der sogenannten "Terra firme".

Die Terra firme unterscheidet sich von den zwei weiteren charakteristischen Großökosystemen Amazoniens, den Überschwemmungsgebieten "Igapo" und "Varzea", im wesentlichen durch a) die vorkommenden Bodentypen und b) den Umstand, daß diese Böden nicht unter ständigem Einfluß von Flußwasser stehen, also nicht überschwemmt werden.

Die typischen Böden der Terra firme sind äußerst nährstoffarme, gelbe Latosole, die einen extrem hohen Verwitterungsgrad aufweisen. Selbst die Tonminerale sind im hohen Maße bis zum Kaolinit verwittert. Bei der Verwitterung oder beim Abbau organischen Materials entstehende lösliche Substanzen werden in so beschaffenen Böden nicht angereichert, sondern vom Regenwasser als Sickerwasser ins Grundwasser transportiert. Von dort aus können sie in nahe Bäche gelangen.

Der Vergleich der chemischen Zusammensetzung des Regenwassers und solchermaßen gespeisten, abfließenden Bachwassers lieferte ein überraschendes, in seinen Konsequenzen unerhört weitreichendes Ergebnis: Furch (1976) stellte fest, daß sich Regenwasser und Bachwasser eines Terra firme-Standortes nur geringfügig unterschieden. Dies bedeutet, daß unter der ungeheuren Vegetation des amazonischen Regenwaldes keine oder nur nur minimale Mengen an Nährstoffen freigesetzt werden, sondern im Gegenteil eine sofortige Wiederaufnahme sichergestellt wird. So findet sich denn auch der überwiegende Großteil der Nährstoffmenge eines Terra firme-Standortes in der lebenden Biomasse.

Die Schlußfolgerung aus diesen Beobachtungen ist, "daß der Wald de facto *nur auf*, aber *nicht aus* dem Boden wächst, daß er diesen vielmehr nur als Substrat für seine mechanische Fixierung anstatt als Nährstoffquelle benutzt..." (Sioli, 1983).

Zur Sicherung der raschen Recyclisierung von Nährstoffen aus abgebauter Streu verfügen die Pflanzen über verschiedene Anpassungen und Mechanismen, wie z.B. die Fähigkeit, mit mutualistischen Mikroorganismen Symbiosen einzugehen. Hier sind in der Terra firme vor allem die Lebensgemeinschaften mit wurzelbesiedelnden vesikulär-arbuskulären Mykorrhizapilzen zu nennen. Diese verschaffen den Wirtspflanzen ein Aufnahmesystem für Nährstoffe, das in der Lage ist, auch noch geringste Nährstoffmengen bereits am Ort der Freisetzung wieder festzulegen und in den Stoffwechsel einzuschleusen.

Der Regenwald auf den im Projekt untersuchten Flächen wurde vor dreizehn Jahren gerodet, die gesamte Vegetation, einschließlich ihrer Wurzelsysteme unter Verlust des Großteils der Symbionten zerstört und mit Kautschukbaummonokulturen bepflanzt. Schon fünf Jahre später -also noch bevor die Kautschukbäume das erste Mal angezapft werden konnten- wurden die Pflanzungen wegen des Auftretens von Krankheiten so häufig mit Pflanzenschutzmitteln und Düngern behandelt, daß sie als unrentabel aufgegeben werden mußten. Seither lagen sie brach.

So wie in diesem Fall erging es unzähligen solcher Felder. Im Laufe von Jahrzehnten entstand so eine breite Zone ungenutzter, aber logistisch äußerst günstig gelegener ehemaliger Anbauflächen.

Literatur

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Problemstellung
Mindestens 7% des Regenwaldbestandes Amazoniens sind in den zurückliegenden Jahren unter der Zerstörung der primären Vegetation in landwirtschaftliche Monokulturflächen umgewandelt worden. Diese Monokulturen waren als nicht angepaßte Nutzungsform nur für einen Zeitraum von wenigen Jahren zur Erwirtschaftung geringer Erträge geeignet. Abbau der Produktivität durch Fehlbewirtschaftung führte zwangsläufig zur Aufgabe der unrentablen Betriebe. Die Konsequenz aus der mangelnden Rentabilität der landwirtschaftlichen Nutzflächen war und ist, vor allem bei steigenden Bevölkerungszahlen, ein stetig anwachsender Bedarf zur Nutzung "unverbrauchter" Flächen, d.h. in der Regel ein Bedarf an unberührten Urwaldgebieten. Der Großteil der heute brachliegenden oder unrentabel bewirtschafteten Flächen liegt in günstigen Bereichen nahe der großen Städte. Eine Wiedernutzung brachliegender Flächen ist aus ökologischen und marktwirtschaftlichen Gründen geboten.
Die niedrige Bodenfruchtbarkeit, kurze Nährstoffzyklen und die witterungsbedingte Auswaschung von Nährstoffen erfordern eine Entwicklung von Kulturmaßnahmen, die an die besonderen Bedingungen degradierter, brachliegender Standorte in den feuchten Tropen angepaßt sind.

Ziele des Projektes
Das Ziel des Projektes ist die Entwicklung angepaßter Rekultivierungsmaßnahmen für degradierte, brachliegende Kulturflächen unter besonderer Berücksichtigung bodenbiologischer Faktoren, vor allem der symbiontischen Mikroorganismen, sowie unter Einbeziehung der natürlichen Sekundärvegetation d.h. der Pflanzendecke, die nach Beseitigung des Urwaldes spontan nachwächst, in das Pflanzenbausystem.

In diesem Projekt wird den in Vorstudien ermittelten Ergebnissen Rechnung getragen, die belegen, daß bodenmikrobiologische Faktoren (pflanzenwuchsfördernde Bakterien und Pilze) sowie die Artenvielfalt der Vegetation in einer Pflanzung von entscheidender Bedeutung für die zeitliche Stabilität des Agrarökosystems sind und damit eine Grundlage darstellen für eine erfolgreiche Rekultivierung und nachhaltige Nutzung der Bracheflächen.

Ein pflanzenbauliches Kultursystem zur Rekultivierung und nachfolgenden langfristigen Nutzung degradierter, brachliegender Flächen muß vor diesem Hintergrund folgende Voraussetzungen erfüllen:

1. Die Bewirtschaftung muß als Mischkultur angepaßter, einheimischer, mehrjähriger Nutzpflanzen erfolgen.
2. Degradierte Flächen oder solche, auf denen sich Monokulturen befanden, sind auch nach mehreren Jahren Brache noch immer weitgehend verarmt an effektiven, oft für den Pflanzenwuchs essentiellen, Mikroorganismen. Deshalb

ist in der Startphase der Rekultivierungsbemühungen der Einsatz effektiver Symbionten, insbesondere von Mykorrhizapilzen, angeraten.
3. Eine bodenmikrobiologische Stabilität und hohe Artenvielfalt effektiver und an die Standortfaktoren angepaßter Bodenmikroorganismen wird durch möglichst zahlreiche unterschiedliche Wirtspflanzen in den Pflanzungen gefördert. Dies bedeutet, daß die Einbeziehung der natürlichen Sekundärvegetation eine entscheidende Bedeutung für die Stabilisierung der Bodenmikroorganismen-Populationen und damit ebenfalls für die Wirtspflanzen - hier die Nutzpflanzen - hat.
4. Die begleitenden Kulturmaßnahmen müssen so gestaltet werden, daß eine hohe Artenvielfalt der Bodenmikroorganismen gewährleistet bleibt, z.B. muß der Einsatz von Pestiziden vermindert werden.
5. Eine hohe Artenvielfalt der Nutzpflanzen-/Sekundär-Vegetation führt zu einer höheren Krankheitstoleranz des gesamten Pflanzsystems durch eine Veränderung des Kleinklimas im Pflanzenbestand und bringt die Möglichkeit der Etablierung von natürlichen Regelkreisen mit.

Im Projekt werden aus mehrjährigen, einheimischen Nutzpflanzen bestehende Mischkultursysteme unter gezielter Steuerung der bodenmikrobiologischen Verhältnisse und unter Erhöhung der Artenvielfalt der Begleitvegetation getestet.

Neben den biologischen Erfordernissen werden weitere Faktoren beachtet:
6. Die ausgewählten Nutzpflanzen müssen von der Bevölkerung akzeptiert werden und einen Marktwert haben
7. Die Produkte müssen transportfähig sein
8. Die Anlage und der Betrieb der Pflanzung muß rentabel sein
9. Die veränderten Kulturmaßnahmen müssen für den Betreiber einer Pflanzung akzeptabel und praktikabel sein

Gegenwärtiger Stand der Untersuchungen
In den ersten 18 Monaten Laufzeit des Projektes wurde eine 19ha große Fläche parzelliert und Versuchspflanzungen angelegt, in denen verschiedenen Nutzpflanzenmischungen getestet werden. Die Anzucht von pflanzenwuchsfördernden Pilzen (symbiontische vesikulär-arbuskuläre Mykorrhizapilze) wurde unter anwendungsorientierten Bedingungen durchgeführt. Nach dem derzeitigen Stand der Versuche kann bereits von einer erfolgreichen Rekultivierung gesprochen werden. Der Einsatz dieser Mikroorganismen führte zu weit geringeren Auspflanzverlusten, zu einem bisher geringeren Düngeraufwand und verbesserten Resistenzeigenschaften der auf dem Feld befindlichen Pflanzen, so daß neben dem aus ökologischer Sicht günstigen Start auch mit einem ökonomischen Vorteil der neuen Pflanzenbausysteme gerechnet werden darf.

Ausblick
Die Experimentalfläche wird seitens des brasilianischen Partnerinstitutes intensiv mitbearbeitet. Erste Studien zu Krankheitserregern und deren Kontrolle sowie erste insektenkundliche Studien sind angelaufen. Die Arbeiten zur Meteorologie und zur Nährstoffdynamik wurden begonnen und müssen weiterentwickelt werden. Die bisherige bilateral entwickelte brasilianisch-deutsche Konzeption macht diese Versuchsfläche zu einer für viele Gruppen und viele Fragestellungen geeigneten Versuchsanlage, deren Wert mit den nunmehr kontinuierlich ermittelten klimatischen (Feuchte, Temperatur, Niederschlag), bodenkundlichen (Nährstoffgehalte, Nährstoffbindung) sowie bodenbiologischen Grundlagendaten (Art und Anzahl von Bakterien, Pilzen und tierischen Kleinstlebewesen) stetig ansteigt.
Mit der Entwicklung der experimentellen Mischkultursysteme beginnt diese Fläche über den experimentellen Charakter hinaus die Funktion einer Demonstrationsfläche für neue landwirtschaftliche und pflanzenbauliche Maßnahmen am brasilianischen Institut zu werden und wird in Ansätzen bereits dazu genutzt.

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FORSCHUNG

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Deutsch-brasilianisches Botanikprojekt

Erfolgversprechende Rekultivierung brachliegender Flächen in Zentralamazonien

30 Kilometer östlich der brasilianischen Großstadt Manaus, inmitten ursprünglicher Regenwälder der feuchten Tropen Zentralamazoniens, arbeiten seit anderthalb Jahren brasilianische und Hamburger Biologen in einem Projekt zusammen, das die "Rekultivierung brachliegender Monokulturflächen" zum Ziel hat. Der Regenwald auf den untersuchten Flächen wurde vor 13 Jahren gerodet und nur mit Kautschukbäumen bepflanzt. Fünf Jahre später wurden diese Kulturen wegen Krankheit und Unrentabilität aufgelassen und lagen seither brach. Aus zahlreichen solcher Felder entstand in den vergangenen Jahrzehnten eine breite Zone ungenutzter, aber logistisch äußerst günstig gelegener ehemaliger Anbauflächen.

Prof. Dr. Reinhard Lieberei und Dr. Falko Feldmann vom Institut für Angewandte Botanik der Universität Hamburg und ihre Kollegen vom Nationalen Forschungszentrum für agroforstliche Systeme in Zentralamazonien in Manaus haben inzwischen eine 18 Hektar große Fläche parzelliert und Versuchspflanzungen angelegt, in denen verschiedene Mischungen aus mehrjährigen angepaßten einheimischen Nutzpflanzen getestet werden. Die Zucht pflanzenwuchsfördernder Pilze erwies sich dabei als sehr nützlich. Bereits jetzt können sie von einer erfolgreichen Rekultivierung sprechen; denn der Einsatz dieser Mikroorganismen führte zu weit geringeren Auspflanzungsverlusten, zu einem bisher geringeren Düngereinsatz und verbesserten Resistenzeigenschaften der auf dem Feld befindlichen Pflanzen. Neben dem aus ökologischer Sicht günstigen Start darf auch mit einem ökonomischen Vorteil der neuen Pflanzensysteme gerechnet werden.

Die deutsch-brasilianische Forschergruppe macht sich Erkenntnisse aus Vorstudien zunutze, die belegen, daß pflanzenwuchsfördernde Bakterien und Pilze sowie die Artenvielfalt der Vegetation in einer Pflanzung von entscheidender Bedeutung für die zeitliche Stabilität des Agrarökosystems sind und damit eine Grundlage darstellen für eine erfolgreiche Rekultivierung und nachhaltige Nutzung der Bracheflächen. Deshalb muß der Einsatz von Pestiziden vermindert werden.

Eine hohe Artenvielfalt der Nutzpflanzen-Vegetation führt zu einer höheren Krankheitstoleranz des gesamten Pflanzensystems durch eine Veränderung des Kleinklimas im Pflanzenbestand und ermöglicht die Etablierung natürlicher Regelkreise.

Die Wissenschaftler legen Wert darauf, daß die Bevölkerung die ausgewählten Nutzpflanzen akzeptiert und daß diese einen Marktwert haben.

Die bisher von Brasilianern und Deutschen entwickelte Konzeption macht diese Versuchsfläche zu einer für viele Gruppen und viele Fragestellungen geeigneten Versuchsanlage, deren Wert mit den nun auch kontinuierlich ermittelten klimatischen (Feuchte, Temperatur, Niederschlag), bodenkundlichen (z.B. Nährstoffgehalte) sowie bodenbiologischen Grundlagendaten (Art und Anzahl von Bakterien, Pilzen und tierischen Kleinstlebewesen) stetig ansteigt.

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