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IMPROVING MANAGEMENT PRACTICES FOR BIOMASS (FRUIT) PRODUCTION FROM NATIVE STANDS OF BABASSU PALMS AND DEVELOPING TECHNIQUES FOR IMPROVING EXPLOITATION OF THIS TROPICAL PLANT RESOURCE

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Improving Management Practice For Biomass (Fruit) Production From Native Stands of Babassu Palms and Developing Techniques for Improving Exploitation of This Tropical Plant Resource

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IMPROVING MANAGEMENT PRACTICES FOR BIOMASS (FRUIT) PRODUCTION FROM NATIVE STANDS OF BABASSU PALMS AND DEVELOPING TECHNIQUES FOR IMPROVING EXPLOITATION OF THIS TROPICAL PLANT RESOURCE

1. Introduction

The babassu palm (Orbignya spp.), a palm growing native from the humid southern fringes of the Amazon Basin, to the drier landscapes of northeastern and central Brazil and eastern Bolivia, is one of the most important examples of the use of a tropical forest species by people. Distributed over an area of more than 200,000 Km^2, it is recognized as a plant that can be managed as a permanent and stable economic crop of significant value. (Balick, 1984). The babassu palm is a versatile plant with many uses to both the individual subsistence farmer on whose land it is often found as well as to those involved in larger agro-industrial activities (May, 1986). The palm is an important source of market and subsistence products and a crucial resource for rural poor who uses the leaves for thatch, to weave mats and covers, to construct walls, as an edible fruit, and oil, or to feed domestic animals, as an edible palm heart a valuable fiber source, and for charcoal derived from the hard fruit endocarp.(Table 1).

On a larger scale, the babassu palm is the most important native source of lauric oil in Brazil, widely utilized in industry. Some of its other products such as fiber, starch and charcoal also have enormous importance in local markets where the palm occurs and constitutes a valuable source of income for over two million people who are directly or indirectly involved in collecting and breaking the fruits for kernels or charcoal production. This activity comprises the largest commercial oil seed industry in the world completely dependent on a wild plant as its source of raw material. (Markley, 1971).

The babassu palm forms oligarchic stands (Peters et al., 1989) over extensive portions of Brazil, especially in the northeastern State of Maranhão, where the palm attains its greatest distribution and economic importance, covering an area over 10 million hectares. Approximately 77% of the total production of babassu is located in Maranhão State (Pick et al., 1985).

Due to its importance as a source of numerous products as well as for its great potential for improving degraded sites, the Institute of Economic Botany of The New York Botanical Garden in collaboration with Centro Nacional de Recursos Genéticos-CENARGEN and Empresa Maranhense de Pesquisa Agropecuária-EMAPA has been working toward improving and domesticating the palm, as well as developing management practices for its in-situ utilization. As result of these collaborative efforts, numerous studies in different areas have been carried out, involving research on

agronomic, sociological, technological, economic and biological aspects of the palm and its exploitation.

As part of the current program for improving the management of the palm, and working towards its domestication, the Institute of Economic Botany, EMAPA (Empresa Maranhense de Pesquisa Agropecuária), CENARGEN (Centro Nacional de Recursos Genéticos e Biotecnologia), and IICA (Instituto Interamericano de Cooperação para a Agricultura) have collaborated since 1989 on a U.S.AID-funded project "Improving Management Practices for Biomass (Fruit) Production from Native Stands of Babassu Palms and Developing Techniques for Improving Exploitation of this Resource". The overall goal of the project is to improve the utilization of the babassu palm resource through a series of objectives, as discussed in the following sections. Three experiments were installed in the State of Maranhão, and one in the State of Pará, as components of the project. The experiments in Maranhão, were carried out in different areas of the state using EMAPA's Research Stations in two ecological regions. Together, they constitute yet another step towards improving the management and cultivation of the babassu palm.

Table 1. Subsistence Uses of the Babassu Palm. (Source: Anderson et al., 1991 - adapted from May et al., 1985).

LEAVES

Fibers
- Baskets for storage and transport
- Mats for doors, windows, rugs, grain-drying
- Fans for ventilating fires
- Sieves for sifting manioc flour and rice
- Other uses: twine, torches, whisks, bird cages, hunting blinds, animal traps

Construction Materials
- Thatch for roofing and walls
- Laths for window frames and support of clay-packed walls
- Rails for fencing to protect agricultural plots from animals and delimit hunting zones

Agricultural Uses
- Leaves burned in shifting cultivation plots to promote nutrient recycling and pest control
- Stakes used for crop support and elevation of planters
- Living leaves provide shade for livestock and feed during dry periods

Medicine
- Liquid expressed from rachis used as antiseptic and styptic

STEMS

Construction
- Entire stems used to make bridges, foundations, benches

Food
- Palm heart used as food for people and animals
- Sap collected from stumps of felled palms used in fermented drinks
- Burned stems for manufacture of salt by indigenous groups

Attraction of Game
- Sap collected from stumps of felled palms used as attraction of beetle larvae that are eaten or used as fish bait

Horticulture
- Decayed stems used as mulch and planting medium

FRUITS

Food
- Kernels consumed raw as snack nut
- Milk produced from kernels used as beverage or for stewing meat and fish
- Oil extracted from kernels used for cooking
- Residues of kernels used as animal feed and substitute or filler for coffee
- Beetle larvae extracted from kernels used as food for people
- Flour made from mesocarp used as substitute for manioc
- Flour made from mesocarp used to make chocolate-like beverage

Medicine
- Liquid endosperm used to treat sties and bleeding
- Tar from burning husks rubbed on gums to alleviate toothaches
- Flour made from mesocarp used to treat gastrointestinal complaints

Fuel
- Charcoal from husks used as principal source of fuel for cooking
- Oil extracted from kernels used for burning in lamps
- Entire fruits used as fuel to smoke rubber

Attraction of Game
- Fruit mesocarp serves to attract rodents
- Residues of kernels used as shrimp and fish bait

Handicrafts
- Fruit endocarp used to make pencil holders, keychains, figurines

Other Uses
- Oil extracted from kernels used to make soap
- Beetle larvae extracted from kernels rubbed on bows to increase resiliency
- Smoke from charcoal production used as insect repellent

2. Development of a Rapid Technique for Field Determination of Kernel/Fruit (kf) Ratio.

At present, germplasm of natural populations (fruits) is collected in a systematic way, and taken back to the sponsoring institution where it is characterized to determine kernel\fruit (kf) ratio. The results are often surprising - high yielding populations (or individual trees within populations) are identified (such as with up to 18% kf ratio as compared to normal kf ratio of 7%); but by then it can be too late to collect additional material or focus more intensively on studies of that population or individuals. The objective of this part of the project was the development of a standard protocol for collecting, drying (in a portable oven), sectioning and weighing the fruits, utilizing a portable balance, in order to be able to do this type of characterization in the field, and refocus collecting priorities and activities during the expedition, rather than having to return to the original site at a later date. For this work, the equipment to be utilized must be small and light weight for easy transportation and handling in the field. We decided to use a portable oven for drying the fruits. It measures 32 cm long X 43 cm wide X 39 cm high and weighs only 8 kg. The oven is powered by butane gas from a 3 kg container. The temperature in this type of oven were calibrated to three different levels: Low = 200°C; Medium=300°C; High = 400°C. To weigh the fruits a portable LCD electronic balance was purchased, with the capacity of up to 1,000 g. The data

collection was done during two different phases of drying, involving different lengths of time for heating the fruits in the oven.

For the first drying phase, the fruits were collected directly from the palm trees and immediately weighed; 20 fruits were taken and their initial weight determined. The subsequent weightings were done every 2 hours with the fruits being dried in the oven under 300°C temperature. Table 2 shows the weights of the fruits and the percentage moisture at those periods.

For the second drying phase, 10 fruits were utilized and also submitted to a medium level temperature (300°C) and weighed every 30 minutes. The weights and percentages are shown in Table 3.

At the conclusion the total drying period (4 hours, 20 minutes for the first phase and 3 hours for the second phase), the fruits were allowed to cool and then they were cracked open in order to measure the components.

The main objective of this test was the determination of reasonable period of time for rapid drying of fruits to allow characterization of the percentage of components (kf ratio) in the field. It was observed that a long drying period (more than 2 hours), produces excessive loss of moisture leaving the fruits brittle and, sometimes carbonized even in the inner layers. We concluded that, using the portable oven methodology two hours

maximum is recommended for drying babassu fruits; up to this point the loss of moisture reaches 20%, that permits easy fruit breaking and removal of components for determination of kf ratios. More than two hours of exposure to the heat results in the burning of the components and a good characterization is not possible. However, for field work, we believe that the period of drying should not exceed one hour as a practical procedure and in order to effectively utilize time during the collection activities. The oven utilized was satisfactory for this purpose and its size and weight were very convenient for field work (Apendix I, Photos 1 and 2).

Table 2. Weight (g) of babassu dried fruits and percentage of moisture loss measured at 2 hours intervals.

Fruit/ Number	Initial Weight(g)	First Weighing(2 hrs.) g	% Loss	Second Weighing (4 hrs.) g	% Loss
01	260	227	12.70	192	26.16
02	286	249	12.94	203	29.03
03	250	208	16.80	166	33.60
04	279	232	16.85	162	41.94
05	217	171	21.20	149	31.34
06	245	190	22.45	167	31.84
07	231	175	24.25	139	39.83
08	293	233	20.48	197	32.77
09	255	230	9.81	155	39.22
10	247	204	17.41	182	26.32
11	246	229	6.92	180	26.83
12	183	145	20.77	130	18.97
13	282	263	6.74	205	27.31
14	241	215	10.79	163	32.37
15	213	196	7.99	140	34.28
16	251	224	10.73	191	23.91
17	256	225	12.11	165	35.55
18	211.5	163	22.94	137	35.23
19	231	181	21.65	155	32.91
20	214	157	26.64	140	34.58
Mean	244.5	205.8	16.11	165.9	32.20
SD	27.53	31.59	6.07	22.78	5.51

Table 3. Weights (g) of babassu dried fruits and percentage of moisture loss measured at 30 minute intervals.

Fruit/ Number #	Initial Weight (g)	1st (30min) g	%Loss	2nd (60 min) g	%Loss	3rd (90min) g	%Loss	4th (120min) g	%Loss	5th (150min) g	%Loss	6th (180min) g	%Loss
01	186	178	4.30	166	10.75	156	16.13	146	21.50	138	25.80	134	27.99
02	238	228	4.20	216	9.24	208	12.60	196	17.64	182	23.53	180	24.37
03	186	180	3.22	168	9.67	160	13.97	148	20.43	138	25.80	134	27.95
04	216	206	4.63	194	10.19	184	14.82	178	17.60	164	24.08	160	25.93
05	140	130	7.15	122	12.86	118	15.72	110	21.43	100	28.58	98	30.00
06	220	210	4.55	194	11.82	184	16.37	174	20.91	164	25.46	160	27.28
07	238	230	3.37	218	8.41	204	14.29	194	18.49	182	23.53	178	25.22
08	176	166	5.69	154	12.50	146	17.05	138	21.60	130	26.14	128	27.28
09	220	208	5.46	200	9.10	192	12.73	176	20.00	166	24.55	164	25.46
10	254	244	3.94	234	7.88	224	11.82	212	16.54	198	22.05	194	23.63
Mean % Loss			4.65		10.24		14.55		19.61		24.90		26.50
SD			1.11		1.62		1.68		1.78		1.72		1.87
Mean Weight	207.4	198.0		186.6		177.6		167.2		156.2		153.0	
SD	32.98	32.74		32.23		30.64		29.55		27.93		27.61	

3 - Ecophysiological Studies of Two Species of Palms: Babassu (Orbignya phalerata Martius) and Inaja (Maximiliana maripa (Corr. Serr.) Drude)

3.1. Introduction

In the north of Brazil, there are extensive areas that have suffered an accelerated process of deforestation and are in a state of abandonment and degradation. This situation makes the search for strategies for the recuperation of degraded areas most urgent. Some of these species show great adaptation to environmental extremes, such as light and temperature and the availability of water, in relation to the modification of forests in cleared areas.

Babassu (Orbignya phalerata Mart.) is an interesting example with widespread use and economic importance (Anderson, 1983; Pick et al., 1985), especially in the low income population rather than in the landowners. This palm is found in mature forests in low densities (less than 50 plants per hectare), and also in virtually "pure" populations where their dominance is evident (greater than 200 plants per hectare) attaining extensions of 200,000 Km^2 (MIC\STI, 1982). Its occurrence in this latter form characterizes a colonization of secondary vegetation generated usually as a result of human intervention, and showing the great ecological success of this species.

The purpose of this work was to test the following hypotheses: the domination of babassu in secondary vegetation is derived from its capacity to tolerate the stress associated with cleared areas. To better evaluate the responses of babassu we carried out a comparative study with Inaja (Maximiliana maripa) based on the great genetic and ecological similarity shown by these two species of palms (Anderson & Balick, 1988). However, Inaja apparently has less success in establishment in areas that suffer disturbances because it is not found forming populations of great extension and density.

3.2. Materials and Methods

This study evaluated the following parameters: 1) growth in the field; 2) growth in the greenhouse; 3) ecophysiological responses in the greenhouse.

3.3.Growth in the Field

This phase of fieldwork was initiated in May, 1985 in an experimental area of EMBRAPA, the Fazenda Vitoria, in the municipality of Paragominas, Para State. The experimental design was Latin Squares, whereby eight combinations of three treatments were established as follows: 1) light (shading with SOMBRITE 60% vs. exposure to sunlight), 2)

water (with irrigation and without irrigation)[1] and competition (with pasture and without pasture). Each combination was repeated in 4 sub-parcels, totaling 32 sub-parcels. In each sub-parcel, ten lines of babassu with five fruits per line (50 fruits) were planted and five lines of Inaja with five fruits per line (25 fruits) were planted.

A first evaluation of this phase of field work only was possible in May, 1986, one year after the establishment of the experiment. This was due to the long period required for seed germination of these species. We did not consider any attempt for measuring the germination rates, because we believe that at that point several factors could have already influenced this factor, masking the real rates. We took measurements of the seedling length (repeated in February and November, 1987), completing an evaluation period of 2.5 years. The lengths taken by the last measurement were used for statistical analysis of the species responses to treatments.

3.4. Growth in the Greenhouse

This phase of the work started in July, 1987, at the Centro de Pesquisas do Trópico Umido (EMBRAPA\CPATU), in Belém (Pará). In the greenhouse, two seeds of each species were planted in 40 plastic containers of 5 cm diameter. Regular soil was utilized as substrate for seed germination. The soil was collected at the Fazenda Vitoria, in

[1] The irrigation was carried out twice per week, when there was no occurrence of rain equal or greater than 5 mm. The quantity of water used was 5 liters per parcel without irrigation and 10 liters per parcel that had irrigation.

Paragominas (PA) where the field work was carried out. The containers were kept under SOMBRITE 60% until an average of two leaves was obtained per individual. Irrigation of seedlings was proceeded using the quantity of water considered to be sufficient for an uniform seedling growth and development.

After the seedlings developed two leaves, the containers were distributed in an experimental design of randomized plots, and four combinations of two treatments were established as follows: 1) light (shade under SOMBRITE 60% vs. exposure to sunlight) and, 2) water (irrigation at the soil field moisture capacity vs. irrigation hardly enough to avoid the wilting point)[2]. Each combination was replicated in 7 containers for babassu and in 10 containers for Inaja; this difference in the number of replications was a consequence of the different number of germinated seeds of each species. Throughout the period of data collection (June, 1988 -March, 1989), the length of seedlings was measured biweekly. Also in this case, the last measurement was used for comparison between the two species.

3.5. Ecophysiological Responses in the Greenhouse

During the last evaluation, the water potential of the leaves was determined by observing and measuring two physiological processes: 1) loss of turgor and, 2) stomatal opening. Both physiological processes are important because plant growth and several other

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[2] The seedlings treated with irrigation received water until the full capacity of the container three times a week. Those seedlings treated without irrigation received water only once a week.

metabolic activities depend upon turgor, as well as photosynthesis is dependent on diffusion of gases through stomata. This evaluation was made possible by using a photometer (Li-cor 1600) and a Scholander Pressure Chamber. The evaluation of the physiological parameters only was possible at the end of the experiment because of the long time required by the seedlings to develop two leaves per individual.

3.6. Results and Discussion

Growth in the Field

Babassu gave a better performance in all treatments (Table 4), with an average final growth much higher than Inaja, that only had good performance in those treatments with limited conditions of stress (e.g. shade with and without irrigation). On the other hand, although babassu seedlings showed higher growth rates in such conditions, they did not show low growth responses under maximum stress (e.g. full sunlight without irrigation).

Table 4. Average Final Growth in the Field After 2.5 Years

	Final Growth Rate in the Field (cm)			
	Shade + Irrigat.	Shade - Irrigat.	Sunlight + Irrigat.	Sunlight - Irrigat.
Babassu W\out Compet.	69.63	54.71	54.92	52.31
Babassu With Competition	66.47	59.77	47.66	47.08
Inaja Without Competition	50.25	42.24	33.31	27.37
Inaja With Competition	30.29	31.77	32.81	27.80

The Analysis of Variance (Table 5)[3] showed a statistical significance between species and between the responses of each species to the treatments.

[3] System for Statistical Analysis developed by Faculdade de Ciências Agrárias do Estado do Pará.

Table 5. Analysis of Variance of Final Growth in the Field

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio	Sig.
Total	64	20,569.43			
Species	1	9,856.27	9,856.27	75.346	**
Competition	1	933.38	933.38	7.14	*
Light	1	765.84	765.84	5.85	*
Irrigation	1	904.73	904.73	6.92	*
Residual	56	7,325.51	130.81		

** = significance level of 1%

* = significance level of 5%

To confirm the significance of the difference favoring babassu, a T Test was applied for comparison of means (Table 6). The result confirmed the same trend shown in Table .

Table 6. Final Growth in the Field

T Test - Significance Level of T: 1% (**) = 2.66
5% (*) = 2.00

Block 1 : Without Competition

Treatment 1 - Shade + Irrigation

Babassu	Inaja
mean = 69.63	mean = 50.25
n = 40	n = 26

s value = 17.47
t value = 3.96 **

Treatment 2 - Shade - Irrigation

Babassu	Inaja
mean = 54.71	mean = 42.24
n = 39	n = 30

s value = 23.31
t value = 2.20 *

Treatment 3 - Sunlight + Irrigation

Babassu	Inaja
mean =54.92	mean = 33.31
n = 40	n = 48

s value = 12.47
t value = 7.75 **

Treatment 4 - Sunlight - Irrigation

Babassu	Inaja
mean = 50.53	mean = 27.37
n = 41	n = 60

s value = 8.42
t value = 4.93 **

Block 2 - With Competition

Treatment 1 - Shade + Irrigation

Babassu	Inaja
mean = 66.47	mean = 30.29
n = 39	n = 14

s value = 14.27
t value = 3.21 **

Treatment 2 - Shade - Irrigation

Babassu	Inaja
mean = 59.77	mean = 31.77
n = 38	n = 11

s value = 20.71
t value = 2.92 **

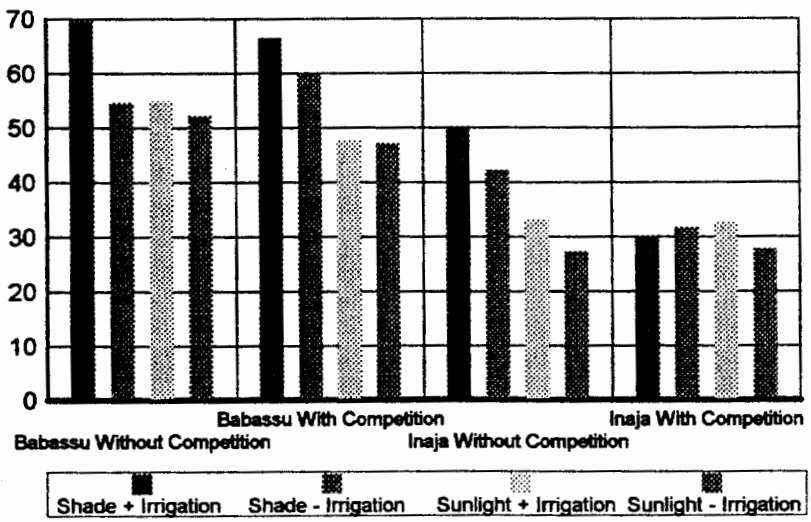
Table 6. (cont.)

```
Treatment 3 - Sunlight + Irrigation
    Babassu                          Inaja
    mean = 47.66                     mean 32.81
    n = 39                           n = 56
                  s value = 12.85
                  t value = 4.79 **
```

```
Treatment 4 - Sunlight - Irrigation
    Babassu                          Inaja
    mean = 47.08                     mean = 27.80
    n = 40                           n = 51
                  s value = 13.26
                  t value = 4.73 **
```

Figure 1 provides a visualization of the final growth of the two species in the field along with the responses to treatments. Both Babassu and Inaja showed a better response when treated in shade plus irrigation. However, when in treatment of shade without irrigation the two species did not overcome the competition, although when in sunlight but with irrigation Babassu was able to overcome the competition.

Fig. 1. Average Final Growth (cm) in the Field After 2.5 Years



Growth in the Greenhouse

In the greenhouse when the variables tested could be more rigorously controlled, the results were practically a repetition of those recorded in the field phase, with Babassu showing better responses in all treatments.(Table 7).

Table 7. Average Final Growth in Greenhouse After 2 Years.

	Final Growth in Greenhouse (cm)			
	Shade + Irrigat.	Shade - Irrigat.	Sunlight + Irrigat.	Sunlight - Irrigat.
Babassu (n=7)	64.2	62.0	55.3	55.1
Inaja (n=10)	33.7	36.5	26.2	24.4

The Analysis of Variance (Table 8) showed a differentiated response between the species and also between the responses of the species to the sunlight treatment. However, there were no differences related to the presence or absence of irrigation.

Table 8. Analysis of Variance [4] for Final Growth in Greenhouse

Sources of Variation	Degrees of Freedom	Sum of Squares	Mean Square	F-Ratio	Sig.
Total	68	63,607.04			
Species	1	15,658.37	15,658.37	330.75	**
Light	1	1,817.74	1,817.74	38.40	**
Irrigation	1	5.84	5.84	0.12	n.s
Residual	65	2,870.42	47.84		

** = significance level of 1%

* = significance level of 5%

This treatment did not show differences because the seedlings that were being normally irrigated, only started being treated after they developed two leaves and this was very close to the last collection of data. Thus, there us a limited period of time in which to obtain statistical differences. The test for comparison of means either did not show any statistical difference (Table 9).

[4] System for Statistical Analysis developed by Faculdade de Ciências Agrárias do Estado do Pará.

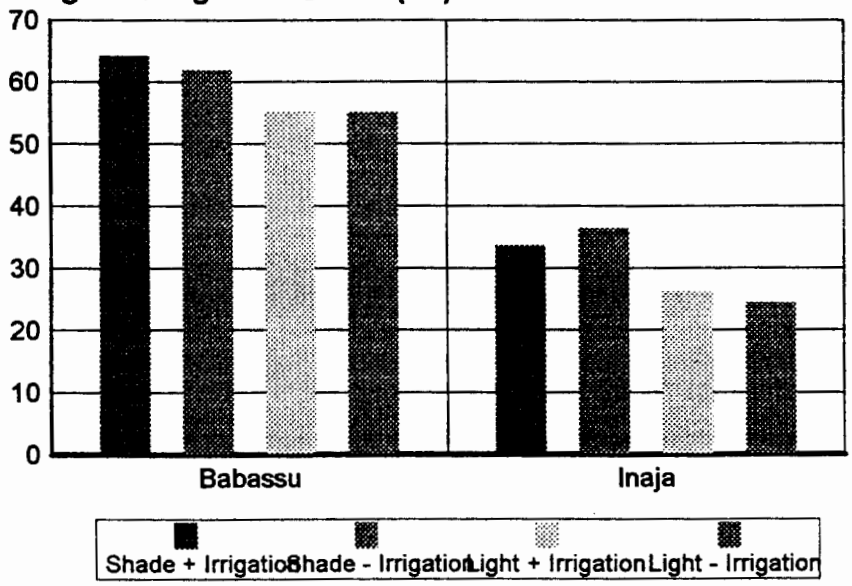
Table 9. Final Growth in Greenhouse

T Test - Significance Level of T: 1% = 2.95
5% = 2.13

Treatment 1 - Shade + Irrigation		
Babassu		Inaja
mean = 64.2		mean = 33.77
n = 7		n = 10
	s value = 3.99	
	t value = 2.03 n.s.	
Treatment 2 - Shade - Irrigation		
Babassu		Inaja
mean = 62.0		mean = 36.5
n = 7		n = 9
	s value = 3.49	
	t value = 1.98 n.s.	
Treatment 3 - Sunlight + Irrigation		
Babassu		Inaja
mean = 55.3		mean = 26.2
n = 7		n = 11
	s value = 6.05	
	t value = 2.07 n.s.	
Treatment 4 - Sunlight - Irrigation		
Babassu		Inaja
mean = 55.1		mean = 24.4
n = 7		n = 6
	s value = 4.34	
	t = 1.80 n.s	

Although there were no statistical differences (probably as a consequence of the great variability of individuals), when we look at the graphs representing the response of the two species to treatments (Figure 2), we find babassu with a growth rate twice as much as Inaja. Again the best growth rate in shade plus irrigation conditions was recorded for babassu; however, in shade without irrigation, Inaja gave better results.

Fig. 2. Average Final Growth (cm) in Greenhouse After 2.5. Years



Ecophysiological Responses in Greenhouse

The water potential measures the amount of free water in the cell walls. When the cell is turgid, the molecules of water are loosely aggregated to the cell wall, easily coming off. On the other hand, when the plant is undergoing water stress and the cell plasmolized, those molecules of water are released only when forced by high pressure. Therefore, a high water potential rate means that the plant is suffering a lack of water.

The rate of diffusion is a parameter to evaluate stomatal opening. The unit for it is time per area which means the quantification of a delta-time necessary for the penetration of gas into the stomatal sub-chamber and its exit. The lower the rate, the greater the stomatal opening, because there will be less obstacles to the circulation of gas.

Both species in all treatments showed a similar ecophysiological behavior - stomata were open in the beginning of the morning, gradually closing later in the morning near midday when the temperature inside the greenhouse became higher. The results (Figures 3 and 4) showed a rate of diffusion lower for Inaja that indicates stomata with greater openings; but in fact, the results mean that Babassu is more efficient in photosynthetic activity as shown by the much higher final growth shown by this species.

This greater efficiency presented by babassu is confirmed by the water potential (Table 10) recorded at 12:00 noon, when the temperature was the highest inside the greenhouse. Inaja was found to be stressed in all treatments, while babassu in sunlight conditions was able to utilize better its defense mechanisms against loss of water through stomata.

Table 10. Water Potential in Greenhouse

Irrigation	Shade - Irrigation	Shade + Irrigation	Sunlight - Irrigation	Sunlight +
Babassu	10.0	10.75	2.5	3.5
Inaja	18.5	20.5	22.0	14.0

Fig. 3. Stomatal Movement in Greenhouse - Babassu

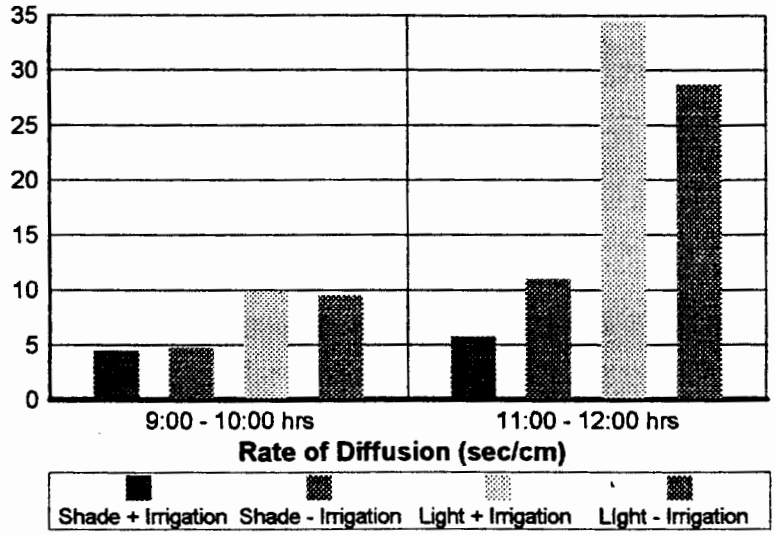
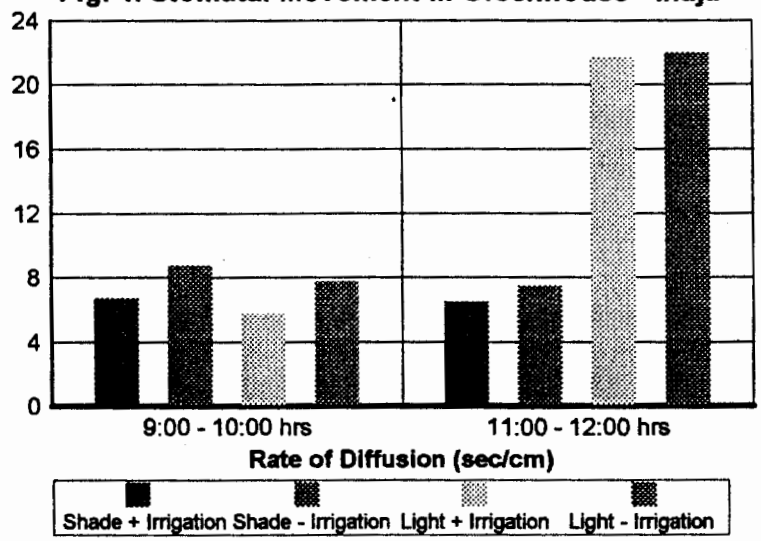


Fig. 4. Stomatal Movement in Greenhouse - Inaja



3.7. Conclusions

We conclude from the different phases of this research, that the most successful establishment of babassu in large populations is based on its greater competitiveness. Its final growth is greater even in stress conditions because of its physiological mechanisms of defense that are adapted to adverse situations. These mechanisms (e.g. an apical meristem underground, a higher rate of diffusion, a lower water potential, and a more efficient photosynthetic activity) allow Babassu a better performance under water stress and competition conditions. Such conditions are characteristic of early successional sites throughout the humid tropics and the results of this study only confirmed what is clearly shown by the presence in nature of the high-density stands of babassu palm throughout the region.

4. Nutrient Requirements of the Babassu Seedling

4.1. Introduction

The babassu palm is a plant species of great ecological success for its ability to colonize large areas of secondary vegetation. The domination of babassu is much more significant in the tropical dry forest of Maranhão (Cocais region), where the predominant Red-Yellow Podzolic soils are relatively fertile in relation to soils over most of Maranhão's territory and the Amazon basin as well (Anderson et al., 1983). The question, therefore, has been whether this palm can grow successfully in other soil conditions and what would be the main responses of the plants to improved soil fertility during its early phases of growth and development.

Different soil conditions produce palms differing in their vegetative growth. Experiments carried out with the African oil palm showed that palms grown under soil conditions that led to a rapid and extended vegetative development, when planted at high or normal density, often failed to respond to fertilizers (Hartley, 1988). The babassu palm represents the opposite situation, forming very dense stands in the wild, with over 10,000 seedlings and juvenile individuals per hectare. The question with babassu is will it respond positively, e.g. with increased yield, to improved growth conditions ? What will these responses be in terms of growth and development? Will

the differences in growth and biomass production resulting from fertilization be significant enough to justify higher production costs? Is the soil chemical composition more important than its physical structure for growth of babassu seedlings ? To answer these questions and to continue the nursery studies, the experiment described in the following paragraphs was implemented.

4.2. Historical Background

Under the program for domestication of the babassu palm, collection of germplasm and several related projects have been carried out since 1980. The project of germplasm collection led to a series of other studies that included the development of methods and techniques for seed germination and large scale production of seedlings used in the establishment of an ex situ germplasm bank, in 1981 in Bacabal, Maranhão, in a 50-hectare area located at the EMAPA Research Station. This experiment is intended to fill a gap in knowledge of nursery production of babassu, yielding results that on the behavior of babassu seedlings in different types of soil under different fertilization regimes.

4.3. Methodology

This experiment was set up at the EMAPA Research Station in Bacabal, Maranhão, and carried out during a four-year period (1991-1994). The first step in this trial was seedling production. To accomplish this, a small greenhouse (10 x 5 m) was built, in order to provide the necessary protection for the germinating seeds (Apendix I, Photo 3). For germination, plastic boxes (60 x 30 x 20 cm) were utilized with a substrate of medium sized granules of vermiculite (Apendix I, Photo 4). Individual kernels were removed from the fruits, using a technique previously developed for babassu seedling production (Frazão and Pinheiro, 1985; Pinheiro and A. Neto, 1987). The seedlings produced were kept in the germinators until they had 2-3 leaves, and then moved to 20 liter plastic bags with four types of soils (Apendix I, Photo 5). The root system of the seedlings measured on average 10 to 40 cm in length by the time the seedlings were transplanted to the plastic bags.

Four types of soils were used: Sand, Podzolic, Latosol and Plintosol, which were selected as they are the most important types found in Maranhão, in terms of area of occurrence and habitat for babassu stands. The nomenclature used in this paper follows the soil classes recognized in Brazil; however, the approximate equivalent in the USDA system of classification is provided.

Sands (USDA system=Cambic Arenosols) occupy 27,750 Km^2 in Maranhão, ca. 8% of the state's area. They are basically soils with a poorly developed profile, usually deep, sandy (clay contents not more than 15%), with a light texture, well drained, and extremely poor in terms of fertility. In spite of the high quartz content sandy soils are often only weakly acid, with pH values ranging from 6.0 - 7.0, coupled with a high base saturation; cation-exchange is very low due to the low clay content. These soils are continuously aerobic and have very rapid through drainage. Their water-holding capacity is very low and plants usually suffer moisture stress. Their reserve of nutrients is low due to their poor capacity to adsorb and hold nutrients, therefore a supply of fertilizers is required for good crop yields. They normally occur in areas of flat to moderately sloping topography, covered by vegetation such as cerrado, caatinga and dry forests. Native stands of the babassu palm are reported to have low productivity in such soils (less than 1,000 Kg/ha).

Podzolics (USDA system=Red-Yellow Podzolics, Ultisols) constitute the second most important group of soils in Maranhão in terms of area, occupying 91,390 Km^2, ca. 28% of the total surface of the state. These soils were the main areas of babassu stands where one of the highest productivities (2,148.9 Kg/ha, in areas of the Cocais region) has been recorded in the past (MIC/STI, 1982). Today, an extensive portion of the area occupied by Podzolics is now covered by pastures alternating with disturbed babassu stands. These are, in general, well developed soils, mostly of clay texture, that range from low to medium natural fertility. They have thick, acidic and strongly leached upper

horizons that create many problems for agricultural utilization, following removal of natural vegetation. As a consequence, large amounts of fertilizers are required, particularly nitrogen and phosphorus. Podzolics usually occupy areas of flat to undulating topography. The class of Podzolics taken for this experiment was the Red-Yellow Podzolic, sandy-clay texture (12-15% clay), phosphorus deficient.

Latosols (USDA system=Oxisols) are the most common type in Maranhão, occupying 115,260 Km^2, which corresponds to approximately 35% of state's total area. The low nutrient status and low content of organic matter give these soils a very low fertility but they often support high forest. They are, in general, soils of lowlands, occurring on sites that vary from flat to steeply sloping but they tend to be more common on moderate slopes. When the forest is removed and agriculture is practiced, fertility is quickly exhausted, requiring applications of correctives and fertilizers. The upper parts of these soils have free drainage but may become saturated with water during the rainy season. These soils have a clayey texture and clay contents can range from 15% to 35%. Acidity is remarkably uniform with pH values about 5.5. in the surface, decreasing to about 4.5 in the middle horizon then increasing to 5.0 in the mottled clay. Productivity of natural stands of babassu, widespread throughout the areas of Latosols, is reported as low. The type of Latosol used in the experiment was Yellow Latosol, medium texture.

Plintosols (Laterita Hidromórfica; USDA system=Laterite) occupy ca. 14% of the state's territory (47,443 Km^2), and constitute the third most important group of soils. They are highly acid, with low natural fertility, and require chemical correction of pH and fertilization. They usually occupy flat to moderately sloping, agriculturally productive areas. This group comprises soils formed by material that is hard or will harden on exposure and is composed mainly of iron oxides and /or aluminum. They are usually under restriction to percolation of water, subject to the temporary effect of excessive moisture; in general, they are soils of moderate to imperfect drainage, conditioned by the nature of the parental material. This class of soil is characterized by concretions, which under especial drying conditions are termed plinthite. The Plintosol used in the experiment was the Eutrophic type which occurs in areas where the babassu stands are highly productive (also in areas of the Cocais region, with ca. 2,000 Kg/ha). Plintosols currently comprise the main areas of occurrence of babassu in Maranhão.

The experimental design was a factorial arranged as follows. Four fertilizer levels (ranging from 0 to the complete recommended NPK regimen for Elaeis guineensis) were applied to seedlings growing in four types of soil (Table 11). Each treatment combination (soil-level of fertilization) comprised 20 seedlings. Fertilizer was applied quarterly, using a 12-17-10 formula, as used for the Oil Palm. The data were collected as each new application of fertilizer was made. Observations were made of general aspects of seedling development, number of leaves, and length of seedlings. To protect

the seedlings against an excess of sunlight, rain and wind, a close-sided shed was built, using babassu leaves as the main construction material (Apendix I, Photo 6). This shaded nursery measured 20 m long by 6 m wide and the babassu leaves used for thatching were gradually removed in order to permit increasing amounts of sunlight on the seedlings.

The bags with seedlings were put on the nursery at ground area leaving 1m space between lines of bags and 20 cm between bags in the lines (Apendix I, Photo 7). The number of seedlings per treatment had to be reduced from 10 to 5, because of constraints on labor, as this was considered to be a more reasonable number for handling and data collection. Therefore, the experiment was installed with 20 seedlings for each level of fertilization - soil type combination, comprising 80 seedlings per soil type and per level of fertilizers, and totaling 320 seedlings in the whole experiment.

According to the original methodology, fertilization should be initiated at the commencent of the 4th month after transplanting, and thereafter following quarterly applications of fertilizer. However, the first application was made beginning with the 2nd month, as we considered that a two-month period would be enough time for seedlings to recover from the stress of transplanting, and the initiation of subsequent development. The measured doses of fertilizers were directly applied in the bags, followed of irrigation. During the transplanting operation we observed the general

characteristics of seedlings as well as general data on leaf and root development. The treatments were as shown below:

Table 11. Treatment Combinations \ Levels of Fertilization and Types of Soil.

Soils \ Levels of Fertilization	I	II	III	IV
Infertile Sand	0	1	2	3
Podzolic	0	1	2	3
Latosol	0	1	2	3
Plintosol	0	1	2	3

Levels of Fertilization (NPK):

0 - Control (No Fertilization)

1 - 4 g : 1st application - 2nd month
8 g : 2nd application - 4th month
12 g : up to 48th month

2 - 8 g : 1st application - 2nd month
16 g : 2nd application - 4th month
24 g : up to 48 month

3 -12 g : 1st application - 2nd month
24 g : 2nd application - 4th month
36 g : up to 48th month

The final evaluation was made using the following parameters: number of leaves, length of seedlings, number of pinnae, number of roots, and fresh and dried weight of leaves, roots and rhizome. The different parameters were statistically analyzed by year and within year.

4.4. Expected Results

Results from this experiment were expected to provide information on the growth of babassu seedlings in different soil types and under different levels of fertilizations. Additionally, the determination of nutrient requirements for babassu seedlings in nursery conditions would provide the information needed for recommending a regimen of fertilization for babassu seedlings. This experiment was intended to complete the goals of the study on establishment of babassu in degraded soils by generating information and developing techniques for large-scale production of seedlings for reforestation or site restoration.

4.5. Results and Discussion

4.5.1. First Census - Two Months After Transplanting

The first observation was carried out two months after the seedling transplant. No significant effect was expected to happen at this point given the short space of time elapsed after transplanting. This first data collection was carried out as a way to record and characterize the state of the seedlings in relation to growth and number of leaves in the beginning of this experimental phase. Length of seedlings in the experiment at

that point averaged 55.43 cm, ranging from 30-73.5 cm (Table12). Leaf production per seedling averaged 1.98, ranging from 1-3 (Table 14).

Analysis of variance of the treatments for the data collected two months after transplanting showed an overall significance among types of soil (Table 13). No fertilizer had been applied at this point; therefore, any possible differences in the recovery of seedlings after transplanting was probably related to the substrate (soil type). In order to detect possible differences in the growth of seedlings after transplanting that could be produced by the substrate, an exploratory analysis of this first collection of data was carried out. This initial data analysis showed that seedlings grown in sandy soil had the lowest growth rate compared to other soil types. This may mean that seedlings used the natural fertility of the different types of soils and the physical structure of the substrate to recover from the stress associated with transplanting. It is known that among the types of soil utilized in this experiment, Sand was the poorest in terms of natural fertility. Comparison between Sand and the other three soil types showed significant difference difference at 5% level (p=0.0001). Surprisingly, the Plintosol type showed the highest mean seedling length for the period, and the difference between this soil type and the other three was statistically significant at the 5% level (p=0.0001). No statistically significant differences among soil types were detected in the number of leaves produced by the seedlings at this phase of the experiment (Table 15).

Any conclusion about the seedlings' growth performance related to soil type was premature at that point since many other factors could be accounting for the differences observed. However, the overall better recovery of seedlings after transplanting in the Plintosol type is quite noticeable, since one could have expected to obtain better results in the Podzolic type of soil, the natural soil of the Cocais region of Maranhão, where the native stands of babassu are more expressive and more productive.

Table 12. Descriptive statistics for length of seedlings recorded two months after transplanting from the germinators to plastic bags with four types of soil.

Soil	Mean	SD	Range
Sand	49.039	7.257	30 - 68
Podzolic	56.888	8.988	36 - 73.5
Latosol	56.281	8.021	38 - 70
Plintosol	59.513	7.654	39 - 73
Totals	55.430	8.867	30-73.5

Table 13. Anova table for a one-factor analysis of variance on length of seedlings two months after transplanting.

Source	df	Sum Squares	Mean Square	F-test	Prob>F
Between Soils	3	4829.105	1609.702	25.115	0.0001
Error	316	20253.647	64.094		
Total	319	25082.752			

Table 14. Descriptive statistics for number of leaves recorded two months after transplanting from the germinators to plastic bags with four types of soil

Soil	Mean	SD	Range
Sand	2.013	0.112	2 - 3
Podzolic	2.037	0.460	1 - 3
Latosol	1.938	0.460	1 - 3
Plintosol	1.962	0.404	1 - 3
Totals	1.987	0.388	1 - 3

Table 15. Anova table for a one-factor analysis of variance on number of leaves two months after transplanting.

Source	df	Sum Squares	Mean Square	F-test	Prob>F
Between Soils	3	0.5	0.167	1.11	0.3452
Error	316	47.45	0.15		
Total	319	47.95			

4.5.2. Second Census - Ten Months After Transplanting

Three applications of fertilizers were carried out during the 10-month period elapsed after the seedlings were transferred to plastic bags in the nursery. Analysis of the data and results attained, revealed that there were continued significant differences in the growth of seedlings in relation to soil type. Fertilization, however, did not produce any significant effect on seedling growth. The overall mean length of seedlings after ten months after transplanting was 48.84 cm (Table 16), lower than the mean recorded in the beginning of the experiment (55.43 cm). A high percentage of seedlings (54.9%), however, showed an average length ranging from 44.8 to 57.4 cm. Three main factors may be responsible for reducing the overall mean length of growth: 1) the stress caused to the seedlings by the transplanting operation caused many of the older leaves to wither, and new leaves were produced during the recovery period; 2) the number of seedlings that died (18): and, 3) the irregular development of a number of seedlings, caused insects, fungi, excess of moisture, etc., following the transplanting operation. Root fracture is the main cause of blackening off of African oil palm seedlings transferred to bags (Hartley, 1988), and some damage to the root system is inevitable in transplanting bare-root seedlings. The damage to the roots is obviously reflected on growth and development of the seedlings even though seedlings are still being nourished by the seed endosperm. Following transplanting, several abnormalities in

leaf development were observed such as crinkles, rolls and collantes, although the number of leaves produced increased in that period.

The effect of soils on growth of seedlings is still significant, although the p-value (p= 0.0240) was lower than in the previous analysis. Interaction between soils and levels of fertilization was not significant (Table 17). A continued lower growth rate in Sand and a higher rate in Plintosol were recorded keeping to the pattern observed in the beginning of the experiment. Comparison between Sand (the lowest rate) and the other three soil types showed that the difference between them is statistically significant (p=0.0301). Comparison between Plintosol (the highest rate) and the other three types of soil also showed statistically significant differences between the means (p=0.0061). This means that the worst (Sand) and the best (Plintosol) performances among soil types are in fact accounting for the differences observed in growth of seedlings.

Levels of fertilization were responsible for a weak statistical significant effect on the growth of seedlings (Table 17), with a p-value on the borderline of significance (0.0452). Contrasts among the levels showed significance when control (the highest mean) was compared to the other three levels (p=0.0098), and no significance was obtained in the analysis when level 3 (the lowest mean) was compared to the other three (p=0.1576). Neither was significant the comparison between the two lowest overall means among levels (level 1 and level 3). These results mean that only the control was statistically different from the other three levels, which in turn were not

individually different from each other. In other words, the differences in growth among levels of fertilization did not statistically exist at this point of the experiment, and seedlings apparently were doing better in the absence of fertilization. This makes sense, if we keep in mind that the seedlings were still attached to the seed for at least 2-4 months following transplanting, and therefore, still using the endosperm reserves during part of the time between the first and this data collection, though they already had a young, but functional root system.

For number of leaves, the situation was quite different. The overall mean was 5.04 leaves/seedling, which is much higher than that formerly recorded (1.98). The range was 1-7 leaves (Table 18), but the majority of seedlings showed an average number of leaves between 4.5 - 5.2. Analysis of variance did not reveal statistical significance for the means computed for the different soil types (p=0.1263). On the other hand, levels of fertilization produced a highly significant effect on leaf production (p=0.0001). Interaction between soils and levels of fertilization was not significant (Table 19). The highest means were recorded in the control level 0 and in level 1 of fertilization. However, there was no significance between the highest mean (control) and the second higher (level 1) (p=0.3653). Contrast between control and the three levels of fertilizers indicated a significant difference between them (p=0.0043); however, it is clear that major source of variation accounting for the overall significance in leaf production among levels reside in the difference between the lowest mean (recorded for level 3, the highest dose of fertilizers applied). Comparison between level 3 and the

other three levels was highly significance at the 5% level ($p<0.001$). It therefore seems, that the highest dose of fertilizers may be having a deleterious effect on leafing rather than stimulative, a conclusion supported by contrasting the lowest two means (level 3 x level 2) which shows statistical significance for the difference between them ($p<0.0001$). Calculation of the monthly rate of leaves produced for this eight-month period elapsed after the last observation confirms what has been discussed above. The lowest rate was recorded for the level 3 of fertilizers whose seedlings produced only 0.315 leaves/seedling/month, in contrast to the control (0.427), level 1 (0.408), and level 2 (0.383). It is important to point out that the data analyzed for this 10-month period after transplanting certainly reflect the effect of the dry season prior to the collection. Although some irrigation was provided after transplanting, it was quite irregular for most of the period, and this fact must be considered.

Table 16. Descriptive statistics for length of seedlings recorded ten months after transplanting from the germinators to plastic bags with four types of soil

Soil	Mean	SD	Range	Died	Levels	Mean	SD	Range	Died
Sand	46.949	7.277	18 - 61	02	0	51.118	9.306	13 - 69	04
Podzolic	48.556	10.043	13 - 65	08	1	47.644	7.478	27 - 63	07
Latosol	48.649	9.055	29 - 69	03	2	49.039	9.428	7 - 67	04
Plintosol	51.307	9.092	7 - 68	05	3	47.558	9.259	18 - 68	03
Totals	48.665	8.866	7 - 69	18	Totals	48.839	8.868	7 - 69	18

Table 17. Anova table for a two-factor analysis of variance on length of seedlings ten months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	745.444	248.481	3.193	0.0240
Levels	3	622.159	207.386	2.665	0.0482
SoilsXLevels	9	685.386	76.154	0.979	0.4579
Error	286	22258.365	77.826		
Total	301	24311.354			

Table 18. Descriptive statistics for number of leaves recorded ten months after transplanting of seedlings from germinators to plastic bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	4.987	1.110	1-7	0	5.329	0.943	1-7
Podzolic	4.903	1.063	1-7	1	5.192	1.049	2-7
Latosol	5.000	1.123	2-7	2	5.105	1.001	2-7
Plintosol	5.267	0.890	2-7	3	4.545	1.070	1-7
Totals	5.039	4.186	1-7	Totals	5.043	1.016	1-7

Table 19. Anova table for a two-factor analysis of variance on number of leaves ten months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	5.632	1.877	1.921	0.1263
Levels	3	26.047	8.682	8.884	0.0001
SoilsXLevels	9	23.322	2.591	2.652	0.0058
Error	286	279.514	0.977		
Total	301	334.515			

Analysis of the data collected up to this point may not quite reflect the true effect of the treatments on growth and biomass production. As we know, during part of the experiment time (up to ca. 12 months), seedlings were still partially fed by their endosperm reserves, despite the fact that they already had functional adventitious roots. Therefore, we conclude that only from the time the seedling becomes independent from the seed, the analysis could reflect the true effect of fertilizer on seedling development. The seedlings that died after 4 weeks the transplanting was carried out were not replaced; we chose to delete these from the experiment as the development of replacement seedlings would always be lower than the rest of the group's average.

4.5.3. Third Census - Fifteen Months After Transplanting

Seedling growth did not show any significant change since the first observation was carried out 5 months before. The overall mean for the length of seedlings was 54.578 cm (Table 20). This may be considered the same as in the beginning of the observations after the seedlings were transplanted to the nursery. Range of length was 27-84 cm, but 27.2% of the seedlings had length in the interval between 55 and 62.5 cm. The overall monthly rate of growth for the last six months was 1.146

cm/seedling/month. The same rate calculated separately for soils was 1.134 cm/seedling/month; for levels of fertilization this rate was 1.115 cm/seedling/month.

Analysis of variance showed that the differences among the means of the soils and levels were statistically significant at the 5% level, but there was no significant interaction between soils and levels (Table 21). Although not highly significant (p=0.0472), still on the borderline of significance), levels of fertilization continued to show a consistent, but weak effect on the model. The highest mean was recorded for level 0 (control), decreasing as the levels increased. However, comparison between control and the other three levels did not show statistical significance for the difference among the means. Statistical significance only resulted from the comparison between the lowest mean (level 3) and the other three levels (either together or individually). This means that, at this point, it does not make a difference in growth whether fertilizers are applied in different doses or not for level 0 through level 2, but it starts to affect growth negatively as the dose of fertilizers reaches level 3. Babassu seedlings, therefore, are not responding positively to the lower doses of fertilizers, but they are negatively affected by the highest dose.

Soils continued to produce consistent overall major effect on growth of seedlings (Table 21). Consistent also was the value of the means among the soil types: Sand still shows the lowest (52.520 cm) and Plintosol, the highest (57.573 cm) (Table). There was no significant difference between Plintosol and Latosol (p=0.18033), but it existed

when Plintosol+Latosol was contrasted to Sand+Podzolic (p=0.0026). Comparison between the highest mean (Plintosol) and the other three soil types showed that the difference was statistically significant (p=0.0047). Comparison between the lowest mean (Sand) and the other three showed that the difference between them was just barely significant (p=0.0571).

Soil type produced a statistically significant overall effect (p=0.0053) on number of leaves (Table 23), in contrast to the result obtained six months before when there was no statistical differences among the means of growth shown by the seedlings in the four different types of soil. The overall mean for the period was 5.56 leaves per seedling, and the range 2-7 (Table 22). The overall monthly rate of leaves produced for this 5-month period after the previous observation was 0.105. This rate if calculated only for soils is 0.104 leaves produced by seedling per month and a little higher (0.105) if calculated for levels of fertilizers. Plintosol is still the soil type responsible for the highest mean number of leaves produced. Comparison between the highest mean number of leaves produced per seedling (Plintosol) and the other three showed statistical significance for the difference obtained (p=0.0076). On the other hand, the lowest mean (recorded for Sand), when compared to the other three was not significant (p=0.2452) . Except again for Plintosol, where both length and number of leaves seemed to be stimulated by that particular type of soil, the other three types did not show statistically significant differences among their means, compared in pairs or individually, as done also for the analysis of growth.

Levels of fertilization, statistically significant (p=0.0003) at the 5% level (Table 23), showed some interesting results for separate consideration. At this point, the highest mean number of leaves was recorded for level 1 of fertilization, in contrast to the 10-month period analysis when the control showed the highest mean. However, comparison between the control and level 1 showed that the difference between these two means were not statistically significant; neither was the difference between level 1 and level 2, meaning again that there is no difference in leaf production whether fertilizers are applied in doses 1 or 2, or are not applied at all. At level 3, negative results are obtained, apparently decreasing or slowing down the number of leaves produced. This, in fact, seemed to have produced a negative statistically significant difference, which can be confirmed by comparison of the highest dose's mean with the other individual means or pairs of means.

Table 20. Descriptive statistics for length of seedlings recorded fifteen months after transplanting from the germinators to plastic bags with four types of soil.

Soil	Mean	SD	Range	Died	Levels	Mean	SD	Range	Died
Sand	52.520	9.598	27-71	05	0	56.243	10.180	32-84	06
Podzolic	52.797	10.385	27-75	11	1	55.333	10.155	27-80	08
Latosol	55.260	12.113	32-83	03	2	55.133	11.555	27-78	05
Plintosol	57.573	10.425	34-50	05	3	51.653	10.972	28-83	05
Totals	54.590	10.630	27-83	24	Totals	54.590	10.715	27-84	

Table 21. Anova table for a two-factor analysis of variance on length of seedlings fifteen months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	1243.909	414.636	3.669	0.1280
Levels	3	909.051	303.017	2.681	0.4720
SoilsXLevels	9	790.826	87.870	0.777	0.6374
Error	280	31646.463	113.023		
Total	295	34590.249			

Table 22. Descriptive statistics for number of leaves recorded fifteen months after transplanting of seedlings from germinators to plastic bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	5.680	1.164	2-8	0	5.703	0.961	4-8
Podzolic	5.261	0.980	3-8	1	5.847	1.122	3-9
Latosol	5.468	1.154	2-8	2	5.613	1.150	2-8
Plintosol	5.840	1.053	3-9	3	5.120	1.078	2-8
Totals	5.562	1.088	2-8	4	5.570	1.078	2-8

Table 23. Anova table for a one-factor analysis of variance on number of leaves fifteen months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	13.870	4.623	4.332	0.0053
Levels	3	20.771	6.924	6.487	0.0003
SoilsXLevels	9	28.198	3.133	2.935	0.0024
Error	280	298.860	1.067		
Total	295	461.699			

4.5.4. Fourth Census - Twenty-one Months After Transplanting

Twenty-one months following seedling transplant, 5 applications of fertilizers had been made. Shading in the nursery had been reduced 6 months before, leaving the seedlings under ca. 70 % direct sun light (Apendix I, Photo 8). Therefore, at this point, the results of soil and fertilizer variations were expected to reflect a greater difference upon the seedlings.

The overall area of the nursery was doubled in January, 1993 to increase spacing between plants, initially set up with 1.0 m between lines and 0.20 m between plants in the line. At this point it was increased to leave 1.0 m between plants in the line (Apendix I, Photo 9). During the relocating of bags in the nursery, we could then notice that the majority of seedlings had their root system coming out of the plastic bags, growing into the ground in the nursery.

Length of Seedlings - The overall mean recorded for the experiment (94.55 cm) was a considerable average increase in the length of seedlings (39.97 cm), e.g. 6.662 cm a month, since the last observation six months before (54.57 cm). The growth rate by seedling per month computed for all four soil types was 6.62 cm; the same rate for levels of fertilization was 6.64 cm. It ranged from 28 to 178 cm (Table 24), although the majority of seedlings (25.43%) had a mean length between 92 and 108 cm. The

extremes of the range consisted of a few outliers formed by atrophied seedlings (in the lower extreme) and abnormally developed individuals (in the upper extreme).

Analysis of variance clearly reflected the effect of treatments on length of seedlings. For both soils and fertilizer levels a highly significant p-value was obtained from the analysis (0.0003 and 0.0002, respectively), although interaction between treatments was not statistically significant (p=.0505). The results (Table 25) show that as the seedlings were primarily on their own, -- nourishing themselves totally from the substrate they were growing rather than the seed --, soils and levels separately made a difference in the growth rate.

For soils, the highest growth rate mean continued to be obtained in Plintosol (103.90 cm); the lowest, however, was not recorded in Sand as in the previous analyses (Table 24). Podzolic showed the lowest mean among soils (85.71 cm), although the difference between this and the second lowest (Sand=92.44 cm) was not significant (p=0.2046). Neither was there statistical significance when the means for Podzolic and Latosol (95.17 cm) were compared. However, the difference between the highest mean (Plintosol) and the other three others was highly significant (p=0.0001), as was the difference between the lowest mean (Podzolic) and the other three soil types (p=0.0020). These results show that although there was a change in the soil type with the lowest mean growth rate, the differences between Sand, Podzolic, and Latosol are not significant. Therefore, the overall pattern is maintained with the continued

significant differences recorded for Plintosol as compared to the other three types of soil.

In relation to levels of fertilization, the pattern so far observed continues: a decrease in the growth rates as the levels of fertilizer increases. Control (Level 0) again showed the highest mean growth (101.87 cm); the differences, however, between control and the second (Level 1=96.65 cm) and third (Level 2=95.42 cm) means, individually, were not statistically significant. High statistical significance was found (Table 25), on the other hand, for the differences between the highest mean (Control) and the other three levels of fertilization (p=0.0036), as well as between the lowest mean (level 3) and the other three (p=0.00003).

Leaves - The average number of leaves produced since the last observation increased from 5.56 to 5.84 leaves per seedling (Table 26). This represents an average increase of ca. 0.28 leaf produced by seedling in a six-month period (in a rate of 0.046 leaves/seedling/month). This monthly rate of leaves produced per seedling was slightly higher if calculated only for soils (0.047) compared to that calculated only for levels of fertilization (0.044). The range of leaves produced by seedling ranged from a minimum of 1 (atrophied plant, outlier) to 9.

Examining leaf production for this period, in the different types of soil tested, we face an interesting situation in terms of average number of leaves produced. First, analysis

of variance showed that the overall differences among the means computed for soil types of soil were not statistically significant (Table 27); second, among the different types of soil, an alteration of the pattern so far observed was recorded: Plintosol no longer showed the highest mean number of leaves produced, and Sand, was no longer, the lowest (in fact, it was the highest). Comparison between individual and groups of means, however, revealed no statistical significance for the differences among them, except for the difference between the highest mean (Sand) and the other three soil types when taken as a group for comparison.

The explanation for this situation may involve climatic factors. The data used in this analysis were collected right after the dry season in the region. Since the seedlings at that point were not receiving any supplementary irrigation, all the water they got had to come from rain, which is absent in the region from June to November. The data were collected in the beginning of January, after the seedlings had gone through the dry season. In the absence of water, the results show that type of soil does not make a big difference, since biomass production is slowed down.

Examination of the results for levels of fertilization also reveal variation in relation to the results so far recorded for number of leaves. Fertilizers did have a significant effect on leaf production, even in water stress conditions. Overall differences among means were found highly significant ($p=0.0001$). No significant interaction between soil type and levels of fertilization was detected. In relation to the situation observed in the last

observation, the pattern is basically the same: the higher the dose of fertilizer applied the lower the average number of leaves produced by seedling. However, the differences among the means (previously not significant, except when the level 3 was compared) start to get into the significance level. This is true for the comparison between the control and the other three levels ($p<0.0001$); between the lowest mean (level 3=5.14 cm) and the other three ($p<0.0001$); and between the control (the highest mean) and the other individual levels, except level 1 (mean=6.02) where no statistical significance was detected for the difference ($p=0.0698$). It suggests no application of fertilizers and application of the lowest dose basically have the same effect on leaf production (probably not stimulant, but not restrictive, either); from level 2 to level 3, however, the effect is restrictive, or negative.

Table 24. Descriptive statistics for length of seedlings recorded twenty-one months after transplanting from the germinators to plastic bags with four types of soil.

Soil	Mean	SD	Range	Died	Levels	Mean	SD	Range	Died
Sand	92.443	27.657	28-176	10	0	101.877	25.784	50-176	07
Podzolic	85.710	21.244	38-142	11	1	96.658	23.861	50-150	07
Latosol	95.171	30.083	47-178	04	2	95.427	28.703	41-159	05
Plintosol	103.908	25.865	51-156	04	3	83.786	27.365	28-178	10
Totals	94.308	26.212	28-178	29	Totals	94.437	26.428	28-178	29

Table 25. Anova table for a two-factor analysis of variance on length of seedlings twenty-one months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	12578.770	4192.923	6.480	0.0003
Levels	3	13130.506	4376.835	6.764	0.0002
Soils X Levels	9	11124.225	1236.025	1.910	0.0505
Error	275	177946.030	647.076		
Total	290	214779.531			

Table 26. Descriptive statistics for number of leaves recorded twenty-one months after transplanting of seedlings from germinators to plastic bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	6.100	1.276	3-9	0	6.397	0.939	4-9
Podzolic	5.638	1.124	3-8	1	6.082	1.037	4-8
Latosol	5.803	1.296	1-9	2	5.733	1.298	1-9
Plintosol	5.842	0.939	4-8	3	5.143	1.011	3-7
Totals	5.846	1.159	1-9	Totals	5.839	1.071	1-9

Table 27. Anova table for a two-factor analysis of variance on number of leaves twenty-one months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	5.796	1.932	1.685	0.1705
Levels	3	61.105	20.368	17.765	0.0001
Soils X Levels	9	14.719	1.635	1.426	0.1764
Error	275	315.292	1.147		
Total	290	396.912			

4.5.5. Fifth Census - Forty Months After Transplanting

This final collection of data was carried out 19 months after the previous collection, and 40 months after the experiment was installed in the nursery area. At this phase of the experiment the plants had been left under direct sun light for ca.12 months since shading was completely removed (Apendix I, Photo 10). We decided that the experiment should be terminated following this collection of data, since it would be difficult to keep control on the seedlings and monitor the effects of soils and levels of fertilization since other factors also started to interfere with the results. These factors included the significant growth of the root system outside the bags, and the remarkable development of the aerial parts requiring a new increase of spacing that would damage the well developed roots of the seedlings.

Destructive measurements were used in this final collection of data. The seedlings, now over 1.5 m tall on average, were removed from the bags and the roots freed from eventual attachment to the nursery soil (Apendix I, Photo 11). After the seedlings were taken to a working area, the following measurements and counts were taken: length of seedlings, number of leaves, length of rhizome, diameter of rhizome, number of roots, fresh and dry weight of roots, fresh and dry weight of the aerial part, and number of pinnae. The plants parts measured and separated for counting, measuring and fresh weighting (Apendix I, Photos12-15). They were then placed in paper bags and dried in

a dryer built for this particular purpose for 48-72 hours depending on the material (rhizomes usually took longer), at temperature of ca. 70 °C (Apendix I, Photo 16).

Analysis of the data obtained for length of seedlings after the total period of time the experiment lasted (40 months) showed a mean length of 155.12 cm (Table 28), a considerable increase since the previous collection of data (94.55 cm). This represents an average increase of 60.564 cm for a period of 19 months, which in turn represents a monthly average increase of 3.18 cm, the second highest obtained during the entire experiment. Growth rate obtained separately for soils showed an average increase of 3.18 cm per month per seedling, just slightly higher than that obtained for levels of fertilization (3.18 cm). This seems to confirm a pattern observed in nature; babassu seedlings are slow growing in their early phases of development. Length of seedlings ranged from 39 to 240 cm, although the extremes of this range are formed by a few outliers. The highest percentage of seedlings (25.9%) showed length between 144.5 and 165.6 cm. Analysis of variance (5% level) revealed an overall significant effect of soil types of soil ($p=0.009$), levels of fertilization ($p=0.0017$), and surprisingly for the interaction between soils and levels ($p=0.0052$) (Table 29).

The overall significant effect of soil treatments confirmed the previous results. Plintosol kept overall highest mean among soil types, a difference that continued statistically significant when compared to each other type of soil or to the other three as a group. Therefore, Plintosol (the highest mean) compared to Sand, Podzolic and

Latosol as a group is statistically different from them, the same way Podzolic (the lowest mean) shows a difference in comparison to the other three soils that is also significant.

Levels of fertilization also produced an overall significant effect (Table 29). The results obtained in this final collection of data showed what had been preliminarily concluded throughout the final phases of this experiment. Again the control showed the better performance in terms of mean length, followed by the next two levels (1,2), and finally, confirming the negative effect of the highest dose of fertilizers (level 3) on growth rate of the seedlings. No statistical significance was detected for the difference between each of the first three levels (0,1,2), while the differences between these three levels (either as a group or individually) and level 3 (the lowest mean) were always highly significant.

Leafing during this 19-month period turned out apparently to be slower than the growth rate. The average increase in biomass (leaf) production was ca. 0.73 leaf/seedling/19 months. This corresponds to an average monthly increase of 0.038 leaf, very close to that recorded in the previous observation 19 months before for a 6-month period. For this period of 19 months elapsed since the previous data collection, a monthly rate of 0.035 leaves produced by seedling per month was obtained if calculated for soils only; this rate was 0.037 when calculated for levels of fertilizers. This suggests that while growth rate is clearly affected by climatic factors, leaf

production follows a stable rate throughout the year, with little or no variation. It is important to point out that the previous collection of data, as mentioned before, was carried out after the dry season, and this collection was carried out in August, just after the rainy season ended. This fact apparently did not make a difference in the leafing rate recorded from the data collected after these two different seasons. Number of leaves ranged from 1 (outlier) to 10 (Table 30); the majority of seedlings (24.4%), however, bore 6-7 leaves by the time this last data collection was made.

For the first time during the experiment interaction between soils and levels of fertilization had an overall significant on the model (p=0.0383) (Table 31). Although only barely significant it shows that the effect of type of soil may somehow have something to do with effect of fertilizer. Providing that water, the vehicle of absorption and translocation of nutrients is not lacking, the physical structure of soil may be an additive, interactive factor for a combined overall effect. What is not clear, however, is why this effect was produced in leafing, and not in growth. Separate effects of soils (p=0.0001) and levels of fertilizers (p=0.0001) were highly significant.

Anova of types of soils confirmed Plintosol as the type in which the most significant differences were produced in terms of number of leaves (Table 31). The differences between Plintosol (mean=7.395) and the other three types when contrasted as a group or individually (i.e. Plintosol x Sand+Latosol+Podzolic; Plintosol x Latosol; Plintosol x Podzolic; Plintosol x Sand) showed statistical significance, that confirmed the results of

the previous analyses. Contrast between the two lowest means (Podzolic x Sand) detected no significant difference between them, showing these two types of soil as the worst substrates for leafing, confirming the results obtained for growth. Contrast between the lowest mean (Sand) and the other three showed that they are significantly different.

Levels of fertilization also had a significant effect on leafing of seedlings (Table 31). A slight variation from the previous results, however, could be observed. Control (mean=6.53) did not show the highest mean any more; that was held by level 1 (mean=7.05), followed by level 2 (mean=6.53) (Table 30). The differences among them, in contrast with previous analyses, were this time, statistically significant, although not highly so. Individual comparison between the highest mean obtained (level 1=7.05) and the second highest (level 2=6.60) showed a barely statistically significant difference (p=0.050). When the same level 1 is compared to the control, now the third highest mean (6.53), significance is statistically higher than in the former comparison, although still not highly significant. Highly significant differences were found only when the lowest mean (level 3) is compared to the other three, confirming the negative effect of the highest dose of fertilizers on leaf production. Control (level 0) compared to level 3 was not significant.

These results show a slightly positive effect of the lowest dose of fertilizers applied to the seedlings in terms of leaf production. The weakness of this positive effect may be extended to the second highest dose of fertilizers; also, the difference from this to the control was barely significant. In conclusion, dose 1 of fertilizers produces a positive effect (increase) on the number of leaves produced by the seedlings, although it seems that this effect is not significant enough to justify application of fertilizers with its resulting costs. This point may be reinforced by the fact that growth did not increase from application of dose 1 of fertilizers, raising the question why one would add fertilization costs to seedling production in order to have as result a few more leaves per seedling? The initial positive effect becomes increasingly negative as the dose of fertilizer is increased.

Table 28. Descriptive statistics for length of seedlings recorded forty months after transplanting from the germinators to plastic bags with four types of soil.

Soil	Mean	SD	Range	Died	Levels	Mean	SD	Range	Died
Sand	148.197	37.292	57-230	19	0	163.562	33.883	77-238	07
Podzolic	146.246	44.989	39-240	15	1	154.319	28.564	70-207	08
Latosol	160.097	35.162	74-213	08	2	159.072	41.470	57-218	11
Plintosol	164.750	32.801	85-238	04	3	142.783	46.090	39-240	20
Totals	154.822	37.561	39-240	46	Totals	154.934	37.502	39-240	46

Table 29. Anova table for a two-factor analysis of variance on length of seedlings forty months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	21860.479	7286.826	5.644	0.0009
Levels	3	20154.368	6718.123	5.204	0.0017
SoilsXLevels	9	31326.008	3480.668	2.696	0.0052
Error	258	333094.995	1291.066		
Total	273	406435.850			

Table 30. Descriptive statistics for number of leaves recorded forty months after transplanting of seedlings from germinators to plastic bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	5.934	1.263	3-9	0	6.534	1.385	2-10
Podzolic	6.108	1.977	1-10	1	7.056	1.393	4-10
Latosol	6.667	1.278	4-9	2	6.609	1.437	4-10
Plintosol	7.395	1.317	3-10	3	6.000	1.974	1-9
Totals	6.526	1.459	1-10	Totals	6.550	1.547	1-10

Table 31. Anova table for a two-factor analysis of variance on number of leaves forty months after transplanting.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soils	3	99.926	33.309	16.721	0.0001
Levels	3	45.846	15.282	7.671	0.0001
SoilsXLevels	9	36.090	4.010	2.013	0.0383
Error	258	513.950	1.992		
Total	273	695.812			

Also as a character for measuring biomass production during the period of the experiment, data on length and diameter of rhizome were taken in the final collection. The average length of the rhizome was 22.1 cm (SD=0.045), with a range of 9.0-32 cm (Table 32); however, 65.7% of the plants had a rhizome between 21.0 and 28.2 cm long. The most important conclusion of the Anova was a significant interaction between soils and fertilizer levels (p=0.0489) (Table 33). Apparently, effect of soil on the length of rhizomes depended on the level of fertilizer applied. Therefore, conclusions about the differences due to the main effects isolately, would not mean much because of the interaction between them, but analysis of variance showed a significant p-value for soils (p=0.0028), and levels of fertilization was not significant (p=0.0914). The highest overall mean rhizome length for the soils was recorded for Sand (23.8 cm), followed by Plintosol (22.2 cm) (Table 32). Comparison between this pair of means showed no statistical significance for the difference between them (p=0.15182). However, Sand compared to the group of the other three soils was statistically different (p=0.00418), and so it was compared individually to Latosol and Podzolic (p-values: 0.04130, and 0.00024, respectively).

Although with no significant overall effect, levels of fertilization also showed the same constant pattern we have seen for other characters. Length of rhizome, in this case, decreases as the dose of fertilizers applied is increased, in a very regular gradient

from the control (level 0) through level 3. This only confirms that underground biomass production is negatively affected by the higher doses of fertilizers.

Number of pinnae produced per leaf and measured by counting the pinnae in one side of a fully formed leaf ranged from 14 (outlier) to 71, with a great percent of seedlings (44.93%) ranging from 37 to 49. The mean number per leaf was 39.2 (SD=10.20). Again, interaction between soils and levels was statistically significant ((p=0.0321), as in the previously discussed case of the rhizome length. However, the opposite situation was recorded in relation to the main effects: soil type was not significant (p=0.0543), but levels of fertilization was (p=0.0216). As a source of variation in this model is not the separate effect of soils and fertilizer levels, but the combined effect of both, the significant individual effect of each will not be discussed.

Table 32. Descriptive Statistics for Length of Rhizome (m) Forty Months after Transplanting of Seedlings to Plastic Bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	0.238	0.038	0.110-0.320	0	0.231	0.036	0.140-0.320
Podzolic	0.205	0.044	0.090-0.290	1	0.220	0.048	0.090-0.310
Latosol	0.218	0.045	0.120-0.300	2	0.216	0.047	0.100-0.300
Plintosol	0.222	0.048	0.100-0.300	3	0.214	0.047	0.110-0.300
Totals	0.220	0.043	0.090-0.320	Totals	0.220	0.044	0.090-0.320

Table 33. Analysis of Variance for Length of Rhizome Forty Months after Transplanting to Plastic Bags.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soil	3	0.027	0.009	4.819	0.0028
Levels	3	0.012	0.004	2.175	0.0914
SoilsxLevels	9	0.033	0.004	1.925	0.0489
Error	258	0.485	0.002		
Total	273	0.557			

The number of primary roots were counted for each seedling. The average number per seedling was 30.45 (SD=10.297); the highest percentage of individuals (46.34) ranged in the interval of 25 - 37 roots/seedling. Anova showed no overall statistical significance for the difference among the means either in types of soil or levels of fertilization; interaction between them was not significant either. It seems, therefore, that number of primary roots produced by the seedlings in their earlier phases of growth is not affected by the types of soil and doses of fertilizers applied.

The bulky structure formed by the rhizome and roots was also studied as a indicator for biomass produced. It was weighed after separation from the aerial part, and average weight ranged from 84 g (in atrophied plants) to 2.68 Kg (Table 34); the interval with the highest percentage of seedlings (44.89%) weighed between 624-1.16 Kg. Anova showed significant p-values for soils, levels and for the interaction between them as well (p-values= 0.0002, 0.0124, and 0.0003, respectively) (table 35). The

highly significant interaction between the two factors tested, shows at this point of growth, seedlings respond to both soils and fertilizers, and that the response produced in the fresh weight of roots is the combined result of both.

Since the rhizome was also taken with roots for weighing, it would be expected that those seedlings with longer rhizomes would also have the heavier root+rhizome combination, as only the length of the rhizome was significantly affected by the treatments, as previously shown. This is what was observed. For root production, Plintosol was not the best soil for the seedlings, as it was for growth and leaves. For roots, Sand showed the best results, both for rhizome length and weight of roots+rhizome. This makes sense, as the physical structure of sandy soils allow better development of the root system in contrast to Plintosols where the presence of concretions can be obstacles for a good root system development. What is interesting is that the good root development in Sand is not reflected also in good growth of the aerial parts in the same soil -- Sand was the worst substrate in terms of aerial growth. Therefore, when the analysis involves roots, the pattern observed for aerial parts along the experiment for the aerial parts is not confirmed.

Regarding the levels of fertilization, results were as expected. The control still had the highest overall mean (Table 34), which decreased as doses of fertilizers increased. There were no statistical differences between the control and the next two levels (1,2), but the difference between the highest level (3) and the other was highly significant. In

conclusion, fertilizers have no effect until the dose is increased to level 3, when a deleterious effect is produced.

Table 34. Descriptive Statistics for Fresh Weight of Rhizome+Roots (gms) Forty Months after Transplanting of Seedlings to Plastic Bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	1079.08	520.136	92-2686	0	1042.88	452.585	260-2686
Podzolic	722.35	370.074	84-1514	1	909.71	421.393	104-1922
Latosol	974.50	436.187	146-2290	2	896.65	431.431	114-1700
Plintosol	929.88	409.351	114-1852	3	835.23	483.396	84-2290
Totals	926.45	433.937	84-2686	Totals	921.117	447.201	84-2686

Table 35. Analysis of Variance for Fresh Weight of Rhizome+Roots Forty Months after Transplanting to Plastic Bags.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soil	3	3494003.834	1164667.945	6.817	0.0002
Levels	3	1893327.775	631109.258	3.694	0.0124
SoilsxLevels	9	5606380.713	622931.190	3.646	0.0003
Error	258	44077383.616	170842.572		
Total	273	55071095.930			

In relation to the fresh weight of leaves measured right after the seedlings were taken from the bags for the final collection of data, the results (Table 36) showed an overall mean of 847.79 g (SD=501.959). Although the range was 12 (atrophied, outlier) to 2.64 Kg, the majority of seedlings (42.32%) were found in the interval of 558 g - 1.10 Kg. As observed and confirmed in previous analyses, when the aerial part was the object of the analysis, the highest mean was always recorded in Plintosol, decreasing from Latosol to Sand to Podzolic (or sometimes, from Latosol to Podzolic to Sand). In this final analysis the former was true, although statistically, no difference existed between the means obtained for Sand and Podzolic. The same way, Plintosol and Latosol were statistically equal in terms of means for fresh weight of leaves. Since the overall effect of soil type was significant (Table 37), we must conclude that the best soils, among the four tested, in terms of early stage aerial biomass production, are Plintosol and Latosol.

Levels of fertilization confirmed the pattern detected in previous results, showing the same decrease in overall growth, and aerial and underground biomass production, as a consequence of the increase of the dose of fertilizers applied to the seedlings. Although the overall differences among the four levels were not significant (p=0.1414), in terms of means for fresh weight of leaves (Table 37), the pattern so far observed for other characters analyzed was again noticeable: control and the first two levels (1,2) are not significantly different, but as the dose applied goes beyond the second level, it

produces a detectable decrease in the seedling performance, as seen throughout the experiment.

Since a significant interaction was detected by the analysis performed, conclusions should be cautiously drawn. However, some conclusions based on the separate analysis of the main effects could still be made supported by patterns that have been confirmed with or without the presence of possible confounding effects produced by the significant interaction between soils and levels.

Dry weight of leaves also presented similar results to those obtained for fresh weight: types of soil producing a highly significant effect ($p=0.0001$); no significant effect from levels of fertilization, and a significant interaction between these two factors. No major differences can be drawn from dry weight of leaves in relation to fresh weight already discussed. Therefore, the conclusions are basically the same.

In terms of underground biomass production, both fresh and dry weight showed better overall results in Sand, showing that the more open soil structure of this soil is favorable to development of the root system. There is no corresponding similar effect on growth or aerial biomass production. Significant p-value for soils, not significant for levels of fertilizer, and a significant interaction were obtained for both fresh and dry weight of roots, although not statistically different levels of fertilization gave means that decreased from the lower to the highest level.

Since there was an overall significant interaction between the two main factors tested, I cannot easily separate what was in fact the result of the presence of each factor. It seems clear, however, that soils played a positive role for most of the characters measured during this experiment, with the best performances being achieved in Plintosol. Since we have to assume that the factors acted in combination because of the significant interaction showed by the analysis, and that type of soils (at least for two types) was always a positive factor when the interaction was not significant, we must conclude that soils accounted positively when lower doses of fertilizers applied (0,1,2) and levels of fertilization accounted negatively when the worst substrates (Sand,Podzolic) were combined with level 3 of fertilizers.

Table 36. Descriptive Statistics for Fresh Weight of Leaves (gms) Forty Months after theTransplanting of Seedlings to Plastic Bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	773.082	475.725	60-2392	0	913.890	482.851	104-2392
Podzolic	740.369	501.004	12-1864	1	811.278	387.160	80-1620
Latosol	924.333	517.627	92-2642	2	878.870	537.661	62-2054
Plintosol	927.132	491.640	96-2258	3	775.467	595.236	12-2642
Totals	841.229	496.499	12-2642	Totals	844.876	500.727	12-2642

Table 37. Analysis of Variance for Fresh Weight of Leaves (gms) Forty Months after Transplanting to Plastic Bags.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soil	3	2744974.276	914991.425	3.937	0.009
Levels	3	1278708.829	426236.276	1.834	0.1414
SoilsxLevels	9	5953977.650	661553.072	2.847	0.0033
Error	258	59960574.975	232405.329		
Total	273				

Table 38. Descriptive Statistics for Dry Weight of Leaves (gms) Forty Months after Transplanting of Seedlings to Plastic Bags.

Soil	Mean	SD	Range	Levels	Mean	SD	Range
Sand	381.197	231.653	26-1066	0	448.041	245.816	48-1140
Podzolic	333.016	247.164	6-1142	1	418.333	229.047	32-1142
Latosol	504.278	315.268	40-1812	2	426.147	282.795	28-1056
Plintosol	442.553	251.672	42-1130	3	378.383	329.463	6-1812
Totals	415.261	261.439	6-1812	Totals	417.726	271.780	6-1812

Table 39. Analysis of Variance for Fresh Weight of Leaves (gms) Forty Months after Transplanting to Plastic Bags.

Source	df	Sum of Squares	Mean Square	F-test	Prob>F
Soil	3	1378219.993	459406.664	7.029	0.0001
Levels	3	298195.654	99398.551	1.521	0.2095
SoilsxLevels	9	1901816.111	211312.901	3.233	0.0010
Error	257	16796718.046	65356.880		
Total	272	20374949.790			

4.5.6. Death of Seedlings and Its Relation to Soils and/or Levels of Fertilization

A total of 46 seedlings died along the experiment (Table 40). The highest number of deaths was recorded for Sand (19), followed by Podzolic (15), the two types of soils that have been showing the overall worst performances for several characters measured along the experiment. Plintosol showed the best performance also in this regard, with the lowest number of deaths (only 4). When only levels of fertilization is considered in this analysis of death of seedlings, level 3 appears with the highest number of dead seedlings (20) at the end of the experiment, and this number decreases as the level of fertilizers decreases (Table 40). The worst combined performance in terms of deaths was observed in treatments where Sand soil and Level 3 of fertilization were applied.

A test of independence was performed to address the question whether the deaths of seedlings were related to soils and levels of fertilizers combined. For that a 4x4 contingency table was set up and Likelihood ratio (G2-test) and Pearson test were applied. The result (Table 41) was not significant (p-values 0.4268 and 0.4965, respectively or soils and fertilizers), showing that the death of seedlings were independent of the combined effects of Soils and Levels of Fertilizers (or that death of seedlings had the same distribution across the combined effect of soil types and levels of fertilizers).

Table 40. Number of dead seedlings for each soil type and level fertilization recorded at the last census (40 months after transplanting).

Soils Levels	Sand	Podzolic	Latosol	Plintosol	Totals
Level 0	2	3	0	2	7
Level 1	2	4	2	0	8
Level 2	5	3	2	1	11
Level 3	10	5	4	1	20
Totals	19	15	8	4	46

Table 41. Statistical Details for the Test of Independence - Death of Seedlings Across the Interactive Effect of Soil Type and Levels of Fertilizers.

Source	DF	-LogLikelihood	RSquare
Model	9	4.557034	0.0765
Error	34	55.012073	
C Total	43	59.569107	
Test	ChiSquare	Prob>ChiSquare	
Likelihood Ratio	9.114	0.4268	
Pearson	8.378	0.4965	

What if soils and levels of fertilizers were taken separately in order to test the hypothesis of no association between each factor and the observed deaths of seedlings ? For that, two 2 x 4 contingency tables were set up including in each one the observed frequencies of dead and living seedlings for each of the four types of soil and each level of fertilizers (Table 42).

The significance of the independence test (G2-test, p=0.0020; Pearson, p=0.0030) shows a higher probability of seedling mortality in Sand soils than in Plintosol (Table 42). Fig. 5 shows that the probability of mortality is ca. 0.25 in Sand and considerably below this level in Plintosol (ca. 0.05). On the other hand, Fig. 6 shows that as the level of fertilizers increases from control to level 3, the probability for seedling death also increases. The tests performed for this 2x4 contingency table (testing the hypothesis of no association between deaths and levels), resulted significant for both G-test (G2) and Pearson (Table 43), showing that the deaths recorded during the experimental time were associated to the levels of fertilization tested.

Nominal Logistic Regression of seedling survival (dead/living) on levels showed that the probability of predicting seedling death increases as levels of fertilizers increases from the control to the highest dose applied (level 3). In Fig. 7 the left Y axis represents probability, and the proportions shown on the right Y axis represent relative size of each dead/living group of seedlings. A logistic probability curve vertically partitions the total probability of 1 at each point of the levels of fertilizers axis (x). At any point on the fertilizer level axis, the probability associated with the response is the vertical response between the curve on the probability axis corresponding to the response. If levels of fertilizers had no effect on death/survival of seedlings, the fitted line would be horizontal, and the probability would be constant for the response across the continuous factor range. Tests shows significant Chi-Square value for the logistic regression performed (Table 44).

Fig. 5. Contingency Table Mosaic Chart for the Distribution of Seed Mortality Across Types of Soil After 40 Months

Survival By Soils

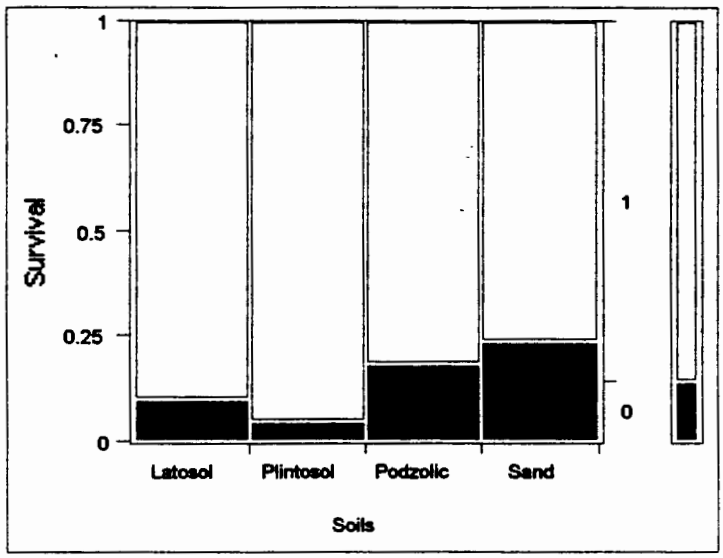


Table 42. Statistical Details for the Contingency Table Analysis for the Distribution of Seedling Mortality Across the Four Types of Soils
Forty Months Following Transplanting

Crosstabs

Survival Count	Soils Latosol	Plintosol	Podzolic	Sand	
0	8	4	15	19	46
1	72	76	65	61	274
	80	80	80	80	320

Tests

Source	DF	-LogLikelihood	RSquare (U)
Model	3	7.39957	0.0562
Error	316	124.34855	
C Total	319	131.74811	
Total Count	320		

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	14.799	0.0020
Pearson	13.913	0.0030

Fig. 6. Contingency Table Mosaic Chart for the Distribution of Seed Mortality Across Levels of Fertilizers After 40 Months

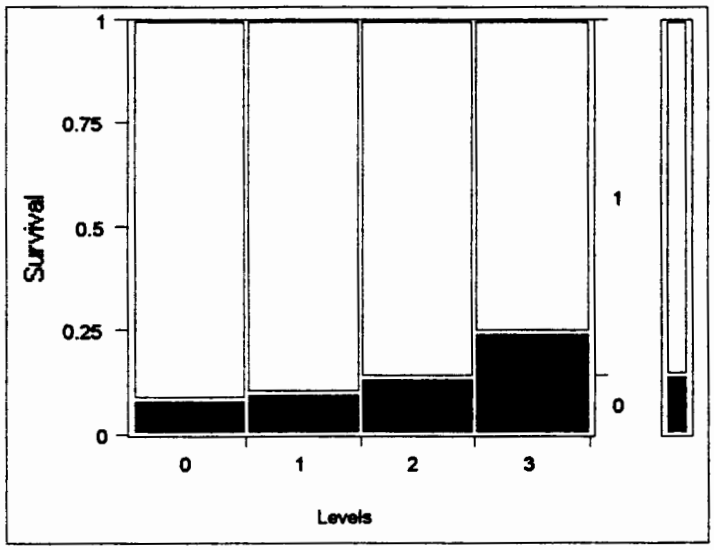


Table 43. Statistical Details for the Contingency Table Analysis for the Distribution of Seedling Mortality Across Levels of Fertilizers
Forty Months Following Transplanting

Crosstabs

Survival	Levels				
Count	0	1	2	3	
0	7	8	11	20	46
1	73	72	69	60	274
	80	80	80	80	320

Tests

Source	DF	-LogLikelihood	RSquare (U)
Model	3	4.98551	0.0378
Error	316	126.76260	
C Total	319	131.74811	
Total Count	320		

Test	ChiSquare	Prob>ChiSq
Likelihood Ratio	9.971	0.0188
Pearson	10.663	0.01

Fig. 7. Graphical Representation of the Nominal Logistic Regression of Seedling Survival on Levels of Fertilizers after 40 Months.

Survival By Levels

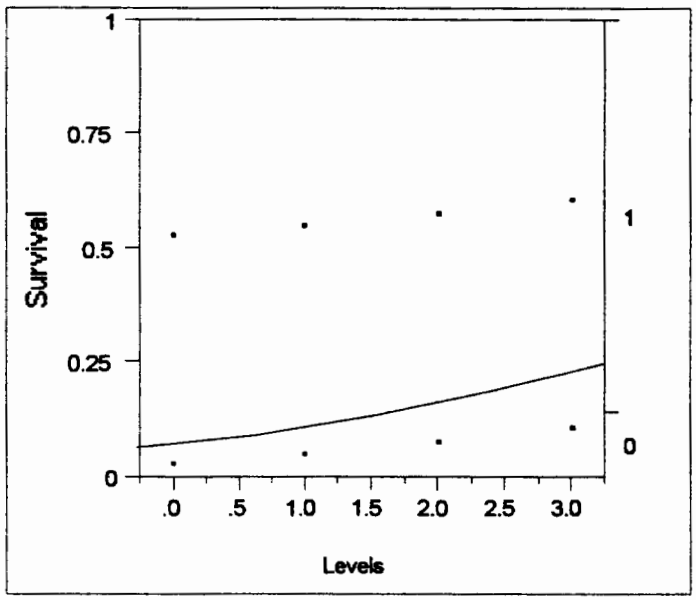


Table 44. Statistical Details for the Nominal Logistic Regression of Survival of Seedlings on Levels of Fertilizers After 40 Months

Whole-Model Test

Model	-LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	4.57584	1	9.151688	0.002485
Full	127.17227			
Reduced	131.74811			

RSquare (U)	0.0347
Observations (or Sum Wgts)	320

Parameter Estimates

Term	Estimate	Std Error	ChiSquare	Prob>ChiSq
Intercept	-2.5396169	0.3290776	59.56	0.0000
Levels	0.44548968	0.1521609	8.57	0.0034

4.5.7. Regression Analysis for Growth and Number of Leaves

Both mean growth and number of leaves per seedling decreases with increasing doses of fertilizers. Simple linear regression performed on data collected at forty months, showed that for each increase in the dose of fertilizers from one level to another, departing from control, the length of seedlings decreased by 5.59 cm (Tables 45 and 46; Fig. 8) The same pattern is observed for leaves regressed on levels of fertilizers: a decrease of 0.19 leaf produced per seedling for each increase in the dose of fertilizer applied (Table 47, Fig. 9). Analysis of variance showed significance for the amount of variation explained by the regression, both for length and number of leaves (p=0.0073 and 0.0276, respectively), although the variation that may be accounted for levels effect on the model is not high (Rsquares= 0.026 and 0.017, respectively for length and number of leaves). (Table 46 and 47).

Table 45. Simple Linear Regression of Length of Seedlings on Levels of Fertilizers

Source	DF	Sum of Squares	Mean Square	F Ratio	Prob>F
Model	1	10420.52	10420.5	7.3075	0.0073
Error	272	387873.36	1426.0		
C Total	273	398293			

Regression

Term	Estimate	Std Error	t Ratio	Prob>t
Intercept	163.41613	3.725984	43.86	0.0000
Levels	-5.594922	2.069712	-2.70	0.0073

Fig. 8. Linear Regression of Length of Seedlings on Levels of Fertilizers

Length By Levels

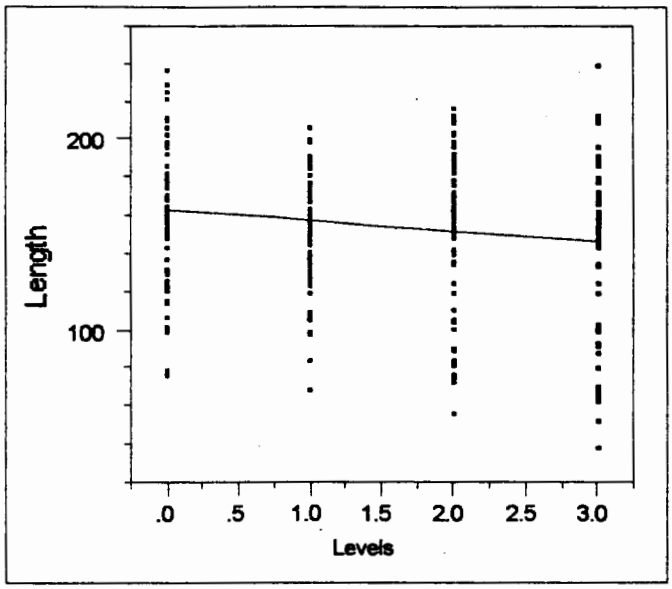


Table 46. Statistical Details for a Simple Linear Regression of Length of Seedlings (Recorded at 40 Months) on Levels of Fertilizers.

Linear Fit

Summary of Fit

RSquare	0.026163
RSquare Adj	0.022583
Root Mean Square Error	37.76248
Mean of Response	155.4526
Observations (or Sum Wgts)	274

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	10420.52	10420.5	7.3075
Error	272	387873.36	1426.0	Prob>F
C Total	273	398293.88		0.0073

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	163.41613	3.725984	43.86	0.0000
Levels	-5.594922	2.069712	-2.70	0.0073

Fig. 9. Linear Regression of Number of Leaves on Levels of Fertilizers

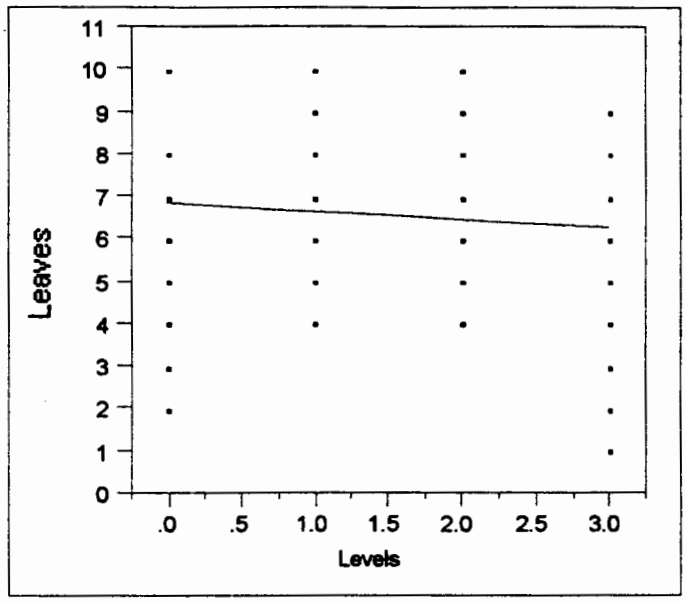


Table 47. Statistical Details for a Simple Linear Regression of Number of Leaves (Recorded at 40 Months) on Levels of Fertilizers

Linear Fit
Summary of Fit

RSquare	0.017715
RSquare Adj	0.014104
Root Mean Square Error	1.57057
Mean of Response	6.572993
Observations (or Sum Wgts)	274

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Ratio
Model	1	12.10031	12.1003	4.9055
Error	272	670.93983	2.4667	Prob>F
C Total	273	683.04015		0.0276

Parameter Estimates

Term	Estimate	Std Error	t Ratio	Prob>|t|
Intercept	6.8443626	0.154967	44.17	0.0000
Levels	-0.190655	0.086081	-2.21	0.0276

4.5.8. Data Transformation

The presence of extreme variates (outliers) was noted in the examination of the data sample for normality. These are due to several factors which include on one extreme, stunted seedlings with imperfect development (in some cases, atrophy) caused by insects, fungi, disease (more rarely), cultural deficiencies (bad planting or insufficient water), or even of genetic origin; on the other extreme, the exaggerated development of individuals caused in a few cases by flaws in the shading, leading to excessive growth, or as observed in seedlings that were growing on ant hills formed in the plastic bag. As pointed out by Sokal and Rohlf (1995), the presence of outliers creating nonnormality conditions in the data sample may not be serious, since according to the central limit theorem, the means tend to follow the normal distribution more closely that the distribution of the variates themselves. Although this data sample did not show a very skewed distribution, data transformation was performed to observe how much the presence of outliers could be affecting the significance level of the F-test and the efficiency of the design.

The data for length of seedlings and number of leaves at 40 months were transformed to normality using the Box-Cox transformation (Sokal and Rohl, 1995). Analysis of variance and regression analysis were again performed using the transformed data for the two variables. The p-values of transformed analyses (both

Anova and Regression Analysis) became in general, lower than those in the non-transformed analyses. This is particularly true for length of seedlings, since number of leaves was not affected by the transformation, showing that extreme variates in the sample cause no effect on the model. In the case of length, the p-values were also lower for the analyses performed with the transformed data, but not lower enough to change the overall results and conclusions (Table 48). This shows that the data meet the overall assumptions required for the analyses performed.

Table 48. P-values Obtained for Transformed and Non-Transformed Data Using Box-Cox Transformation for Length of Seedlings and Number of Leaves at 40 Months.

	Anova P-values Nontransformed		Anova P-values Transformed		Regression Nontransformed		Regression Transformed	
	Length	Leaves	Length	Leaves	Length	Leaves	Length	Leaves
Soils	0.0009	0.0001	0.0019	0.0001				
Levels	0.0017	0.0001	0.0038	0.0001	0.0073	0.0276	0.0174	0.0460
Int.SL	0.0052	0.0383	0.0181	0.0383				

4.6. Conclusions

The results obtained in this experiment showed very clearly that although the type of soils on which babassu seedlings are growing can make a positive contribution in terms of growth rate and biomass production, fertilizers can account for a significant negative effect if higher doses are applied; small amounts such as those applied for levels 1 and do not differ significantly from seedlings growing without any artificial fertilization.

The differences produced by soil types began to appear as soon as the seedlings were transferred from the germinators to the plastic bags. Previous observations revealed that although the seedlings are still attached to seed up to ca. 12 months after initiation of germination, the developing root system suffers from transplanting and requires time for adaptation to the new medium. At the time of transplanting, the root system is functional and much of the nutrients used by the growing seedling come from the substrate. Taking that in consideration, the results obtained following two months after transplanting make a great deal of sense, since the type of soil and its natural fertility can become (as in fact happened) a factor of effect in the recovery of the seedling from the stress associated with transplanting, influencing growth rate and leaf production. Therefore, the first significant results suggest that the seedlings used Plintosol's natural fertility and the little they could get from Sand, making these two soil types, respectively, the best and the worst media for recovery and early growth of

babassu seedlings after transplanting. It seems obvious that other factors contributed to the differences observed in growth rates among soils (that can be detected by the low R-Square), including the inherent genetic vigor, and the ability of individuals to recover from or withstand stressful situations such as transplanting. However, this information on seedling recovery was used as the starting point for the subsequent analyses. Regarding to leaf production, there was no difference among soil types at that point, and this was expected, since the time elapsed from transplanting and the first data collection was only two months, not enough to produce significant variation in that character.

Fertilizers seemed to produce a more consistent detectable effect only during the period between 10 and 15 months after transplantation. Only at 10 months, e.g. 8 months after the seedlings were transferred to the nursery and the first dose of fertilizers was applied, there was a significant difference among levels of fertilization; however, these differences still were barely significant with a p-value on the borderline of the significance level. From this, it was clear that the control performed better in terms of growth rate in comparison with the fertilizer treatments. In a more rigid interpretation of the results, we can say that 8 months after the first fertilization was carried out, no differences existed among the treatments. This finding has practical application, as it shows that early use of fertilizers (up to 1 year) is a waste of money and time. Babassu seedlings will do well enough whether they get receive fertilizer or not, by using the nutrients they still can absorb from reserves of the seed (still

attached) and from the growing medium as well, since the root system is already functional. This is true, at least for seedling growth.

In soils, the situation was quite the same 10 months after transplanting, as expected, since the differences in terms of natural fertility in each type of soil, continued to have an effect on the growth rate of seedlings. What must still be determined is why the differences produced by different soil types on the growth rate were not noticeable in leaf production. On the contrary, the differences among the leafing means were not significant while in relation to levels of fertilizers the means were statistically significant, generating a situation opposite to that already discussed for growth rate. A physiological explanation has to be found for having the same factor producing a barely detectable effect on growth, but highly significant in leaf production.

More consistent results could be obtained for the growth of seedlings only in the 15-month analysis. This is a period of time long enough for the effects of both major treatments to appear. The results indeed confirmed this expectation, showing an overall statistical significance for both soils and fertilizers in the analysis of variance performed with data collected in this period.

The results obtained marked the beginning of a pattern that remained consistent until the end of the experiment: the decrease in both the growth rate and number of leaves produced as the result of the increase in the dose of fertilizers applied to the

seedlings. Although the overall p-value for fertilizers effect was not highly significant at this point, it statistically validated the detected pattern. At this point of the experiment, there was no significant differences between the control and the fertilized treatments; this difference only existed when the highest dose (level 3) was compared to the other levels. It means that the level 3 accounted (negatively) for most of the variation among fertilizers detected in the anova.

This consistent effect of fertilizer, although negative with level 3, may have also partially accounted for the differences observed among soil treatments, where the differences between sand and the other soils diminished, suggesting that as fertilizers start to produce an effect on growth, the differences among soils tend to decrease. This pattern was also observed in leaf production. The difference between Plintosol and the other types was highly significant, confirming consistently, its status as the best substrate to grow babassu seedlings in nursery conditions.

Leafing, at the 15-month analysis, showed no difference in the results whether fertilizers were applied in doses 1 or 2, or were not applied at all. The difference only appeared in the same consistently negative way, with an apparent decrease or slowing down in the number of leaves produced when fertilizer dose 3 was applied.

Both analyses performed on the data at 21 months and 40 months after the seedlings were transplanted mostly confirmed the patterns observed. At 21 months, both soils

and fertilizers continued to produce an overall, highly significant effect on growth. No interaction between effects, however, was detected. In relation to soils, there was only a noticeable change: the lowest means produced up to this point had been those computed for Sand; at this time, however, Podzolic took this position. The fact that a statistically significant difference only existed between Plintosol and the other soil types, individually or as a group, confirmed this type as most beneficial for seedling growth.

In fertilization, a noticeable change was that the differences between control and he other levels were significant as were the differences between level 3 and the others. This shows both extremes (no fertilization and the highest dose) statistically different from the others, leading to the conclusion that fertilizers should not be applied since growth progressively decreases as fertilizer dose increases. In terms of results for number of leaves produced in 21 months, they showed another important change, with Sand having the highest mean among soil types. A possible explanation would only come after the 40-month analysis was performed, when the results revealed that the sandy medium also gave the largest rhizome. A large rhizome perhaps retain higher amounts of water, and that may help the plant to minimize the effects of water shortage during the dry season.

In the final analysis, performed for the data collected 40 months following transplanting, the most important results confirmed most of the patterns obtained throughout the experiment as well as the conclusion stated in earlier analyses. Growth rates obtained for the period (3.18 cm per month in a 19 month-period) were consistent with the situation observed in nature: babassu seedlings are slow growing in their early phase of development. The hypothesis on which this experiment was based – soil type and/or fertilizer regimen could accelerate this growth rate was not proven up to this point in the experiment. However, this considerable increase in seedling length showed after the last 19 months may in part confirm the initial hypothesis, although other factors may have been influential, as discussed throughout this section.

The final results for soil types confirm what has been postulated in the partial analyses: Plintosol had the overall highest mean growth among soils, and this was statistically significant from the others. Based on these results, we can conclude that Plintosol is the best soil type for babassu seedlings, and Podzolic is the worst. However, there is no significant difference between Plintosol and Latosol, raising the latter to the category of good substrate for babassu seedling growth. On the other hand, there is no statistical difference between Podzolic and Sand; therefore Sand is in the category of worst growing medium along with Podzolic. Comparison between Plintosol+Latosol and Podzolic+Sand shows highly statistical significance for the difference between these two groups, confirming the separation as the first two to the group of best substrates and the last two to the category as the worst soil substrates to

grow babassu seedlings. The better growth performance of seedlings on Plintosol and Latosol may have be based on the imperfect drainage shown by these soil types, particularly the first. The retention of water for longer periods of time, especially during the dry season, can make a considerable difference on growth performance. The better results obtained in Plintosol, may be just confirming what is observed in nature. It has been reported that higher productivity of babassu stands is usually recorded in soils of the hydromorphic class, such as that used in this experiment.

The failure of the Red-Yellow Podzolic type used in this experiment is surprising, since this particular type of soil has been the main support for stands of babassu, particularly in the ecological region of Cocais, where the native formations were more expressive in the past, both in terms of productivity and area of occurrence. The explanation may be related to the process of conversion of the original forest to the pastures and agricultural fields during the last two decades. This type of soil is affected by the hydromorphism present in all soils of the region and by the thickness of an originally existing sand layer. As the forest is removed the soil becomes more exposed, producing a decrease of the clay layer on the upper portion of the soil, and an increase of the sand layer. This leads progressively to thicker, more acid and strongly leached upper horizons, with deficiencies in many macro and microelements that make fertilization increasingly important and costly in the agriculture based on these soils. All this, associated to the high rate of conversion of babassu formations and other vegetation to pastures in the region.

Decrease of the clay content, increase of sand content, and leaching of nutrients may be an acceptable explanation for the results obtained in this experiment for the Podzolic type of soil in relation to the expectation that this type would produce the best results. Data on productivity, production and coverage of babassu stands in the Cocais region refers to 15 years ago; we believe, that today, the situation changed considerably, and a new survey of the babassu stands in the area, would show a completely different situation, with lower rates of productivity, production, and reduced area effectively covered by babassu. What seemed to be the best soil environment for the establishment and growth of babassu in the past is no longer true, because of the significant changes in the physical and chemical properties of the soil during the past two decades.

Fertilization was shown to be unnecessary for the early development of babassu seedlings. The final results support the early statement based on the preliminary analysis: addition of fertilizers did not have a statistically significant positive effect on growth of babassu seedlings when the lower doses were applied; however, the highest dose produces a deleterious effect on the growth performance of the seedlings. Throughout the experiment this pattern was observed, and confirmed as statistically significant. Combined effect with types of soil can only be shown after 21 months(in the 19-month period between these two observations) since interaction between these two treatments was never significant up to this point.

Leafing rate at the end of the experiment compared to those obtained before showed that babassu seedlings while having their growth rates clear affected by climate, apparently keep a stable production of leaves both in the dry and rainy seasons. This pattern is confirmed in nature by adult individuals which keep a stable leafing rate throughout the year, and little or no effect of climate has been observed on this phenological event.

In summary, the following general conclusions can be drawn from the results and analyses performed on the data:

1. The early development of the babassu palm (up to 4 years) is very slow.
2. Different types of soils do make a difference in early growth.
3. Fertilizers do not produce a positive significant effect on growth of seedlings up to four years; the slight increase produced on growth and on number of leaves by the first two levels does not justify investment in fertilizers.
4. Higher doses of fertilizers have a negative effect both on growth and biomass production.
5. Leafing rate in babassu seedlings follow the same stable pattern shown by adult babassu palms, being little or not affected at all by climatic changes.
6. Growth rates of seedlings are clearly very affected by cultural care in the nursery.

5. Establishment of Babassu Palm in Degraded Soils

5.1.1. Introduction

Much of the Pre-Amazon region of the State of Maranhão falls into the category of degraded area. This region constitutes a large portion of Maranhão's territory and is bounded by the mangrove areas of the northwestern coast and the *cerrado* vegetation to the south. In the central-western part of this area, much of the originally moist evergreen forest has been devastated by logging and ranching settlements during the past decade. In some areas, the deforestation has been so severe that the soil has been degraded into infertile sand, and the vegetation is now composed mostly of grasses and weeds.

5.1.2. Justification for the Study

For recuperation of areas that suffer deforestation, the utilization of species that regenerate easily and have high economic value is advisable. Many palm species fit this description. As a group they are often adapted to withstand the environmental extremes found in cleared areas. They are also the most important group of plants used by man throughout the tropics and subtropics (Balick and Beck, 1990). The babassu palm (Orbignya phalerata Martius) is considered to be one of the best

examples of use of palms by people. Distributed over 10 million hectares in Maranhão, this palm is more than a source of income for people (Anderson et al., 1991); it is also of great ecological importance, because of its persistence as the main soil cover where other less resilient species have failed. The use of this resilient palm for reforestation of degraded areas in Maranhão, shows great promise for converting unproductive into productive land.

5.1.3. Methodology

This on-site study was designed to test the feasibility of introducing the babassu palm into degraded sites for reforestation and site restoration. It tested the hypothesis that the babassu palm is capable of tolerating the stress associated with cleared areas, degraded soils, and competition. It measured the germination of seeds and seedling growth in control plots (with no treatments) versus plots subjected to shading and weeding. This experiment was installed at the EMAPA Research Station in the municipality of Santa Luzia do Paruá, in the pre-Amazon region of the state of Maranhão. The experimental design used in this experiment was that of randomized complete blocks. The experiment was initially designed with four replications per treatment and eight treatments, totaling 32 plots. The initial treatment combinations planned to be tested were as follows:

Table 49. Original Scheme of Treatment-Combinations

Treament #	Initial Combination
1	Irrigation - Shading - Weeding
2	Irrigation - Shading - No Weeding
3	Irrigation - No Shading - No Weeding
4	No Irrigation - No Shading - No Weeding
5	No Irrigation - Shading - Weeding
6	No Irrigation - No Shading - Weeding
7	No Irrigation - Shading - No Weeding
8	No Irrigation - No Shading - Weeding

However, since irrigation of plots could not be maintained on a regular basis, we decided to eliminate this factor from the combinations tested; as a result, each treatment gained a replication within each block. The experimental design then ended with four blocks, four treatments, 8 replications per treatment, in a total of 32 plots. The final treatment combinations tested are shown in table below.

Table 50. Final Combinations of Treatments Used in the Experiment

Treatment	Final Combination
1	Shading - Weeding
2	Shading - No Weeding
3	No Shading - No Weeding
4	No Shading - Weeding

The blocks were set up in dimensions of 32 x 12 m and divided into eight plots of 2 x 10 m. This experiment was initiated in March, 1989. The seeds were placed horizontally about 5 cm deep in the soil, with 1 x 1 m spacing left between seeds. A total of 39 seeds were used for each treatment, placed in 3 rows of 13 seeds each, and germination was recorded beginning 2 months after sowing. Photos 17 - 21 (Apendix I) provide views of the treatment plots in the beginning of the experiment. Data collection was carried out as follows:

a) Germination: At first, germination of seeds was recorded every two months; however, because of the long time required for germination of whole fruits and the lack of uniformity in germination, we decided that a period of time sufficient to reflect the actual state of germination would be 12 months, which became then the starting point of data analysis.

b) General data collection to record the following information: 1) germination rates; 2) number of established seedlings; 3) number of leaves per seedling; 4) total number of leaves in each plot; 5) length of seedlings. Measurements were made at 1, 2.43, 2.9, 3.3, 4.8 and 5.4 years after the experiment was initiated. The final data collection was carried out using destructive measurements since information on dry weight of roots and leaves had to be recorded. Statistical analysis was carried out on the data collected over the five years of this study, looking for responses of the treatments on

individual parameters, and on the seedlings as a whole in each treatment. The analysis was also oriented to search for among-season and among-year differences in growth and development of seedlings.

5.1.4. Expected Results

The results were expected to provide an idea of the ability of the babassu palm to overcome adverse ecological conditions. If my hypothesis is confirmed, this palm can be included in the list of species recommended for reforestation of degraded areas in Maranhão, and in other parts of Northeastern and Northern Brazil where soil degradation has become a serious ecological problem.

5.1.5. Results

a) First Census (April,1991): One Year after Planting

The first general data collection was carried out after one year, recording information on germination rates, number of established seedlings, number of leaves per seedling, number total of leaves and, length of the seedlings. Data recording on these features followed the procedures described below .

a.1) Seed Germination

Procedures - Whole fruits were used as seeds in this experiment, instead of individual kernels. Since babassu fruits usually have more than one kernel per fruit (2-5, on average), more than one seedling may have arisen from the fruits. However, each fruit was counted as an individual seed and only one germination was considered per fruit, no matter how many kernels germinated. In this way, I could to simplify the experiment and data recording; moreover, the babassu palm is not a clustering species; although many kernels may germinate and produce more than one seedling per fruit, only one plant will survive. Therefore, for the purpose of this study, individual fruits are considered individual seeds.

Results - For this period, the highest germination rate was recorded in treatment 4 (No Shading, Weeding): 57 seeds germinated in this treatment (mean=25.00), which corresponds to 86.4% of total germination in those plots treated with shading and weeding. Treatment 3 (No Shading, No Weeding) showed the second best performance among treatments with 66.66% of germination recorded in the plots (mean=22.75). The lowest rate of germination (31.81%) was recorded in treatment 1 (Shading, Weeding) with a mean of only 17.5 seeds germinated in the plots (Table 51). Analysis of variance for the data (Table 52) showed an overall significant effect of treatments on germination, although not highly significant (p=0.0492). High R-Square shows that ca. 28.2% of the variation in the model was due to treatments effect. The

Least Significant Number (LSN) calculated in the power analysis performed was 31.87, less than the actual sample size n (32). It means that the sample size used in this experiment was enough to achieve a significant result with the given values of the significance level (alpha), the standard deviation of the error (sigma), and the effect size (delta). The power of the analysis for treatment effect (the probability of getting a significant result) was 0.6, a little below the level considered by some as the desirable minimum (0.8). Finally, as expected, no significant effect of blocks was obtained in the anova performed (p=0.9129) , and there was no interaction between treatments and blocks (p=0.5096) (Table 52). No statistically significant difference was found between treatments 3 and 4 (p=0.3788). Neither were there differences between 2 and 3. Comparison between the lowest mean (treatment 1) and the other three, however, showed significance for the difference between the means (p=0.0175), suggesting that treatment 1 accounted for most of the variation in the model, having the lowest means among the treatments. Since the comparison between treatments 1 and 2 showed no difference (p=0.1934), I assume that shading in the treatment combinations may have been the factor responsible for the lowest rates of germination. This is reinforced by comparing the treatments with shading (treatments 1 and 2) with those without it (treatments 3 and 4), which shows that the difference between the means of the two groups is statistically significant (p=0.0168).The treatments under sunlight (both with and without weeding) yielded the best germination results for the period.

Table 51. Descriptive statistics for number of seeds germinated per treatment and block one year after the experiment was installed.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	17.500	6.256	8-26	Block I	20.625	7.836	8-33
Treat.2	20.875	3.136	17-26	Block II	22.375	5.012	12-29
Treat.3	22.750	4.367	16-29	Block III	21.375	4.340	16-19
Treat.4	25.000	4.535	19-33	Block IV	21.750	3.991	17-27
Totals	21.531	4.573	8-33	Totals	21.531	5.294	8-33

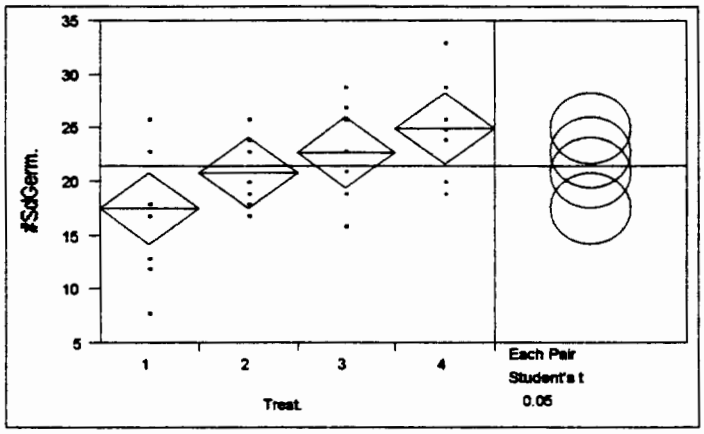
Table 52. Analysis of variance for number of seeds germinated one year after the experiment was installed.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	241.594	80.531	3.258	0.0492	0.2802
Blocks	3	12.844	4.281	0.173	0.9129	0.0149
Treat./Blocks	9	212.031	23.559	0.953	0.5096	0.2459
Error	16	395.500	24.719			0.4588
Total	31	861.969				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	4.971795	2.747691	32	31.87091	0.6332
Blocks	0.0500	4.971795	0.633535	32	484.7945	0.0754
Treat.*Block	0.0500	4.971795	2.574097	32	69.20931	0.3091

Figure 10. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Number of Seeds Germinated by Treatment



a.2) Number of established seedlings

Procedures - Although only one germination per fruit was considered in the analysis of germination rates, the total number of seedlings per plot was counted. The objective of this procedure was to follow the post-germination evolution of seedlings, the progressive disappearance of the least fit, and determination of the final number of seedlings established in each plot-treatment at the end of the experiment.

Results - One year is enough time to measure only the initial establishment of seedlings, since germination did not cease until later than one year, as will be discussed. However, it constitutes a good measure of the effect of treatments on the early development of seedlings in nature, under stressful conditions. The overall analysis of variance showed a significant p-value (0.0406) for treatments as an effect on number of seedlings (Table 54). These results show the importance of light for both germination and for initial establishment of the babassu seedling. Shading conditions seem to have had an initial delaying effect on germination which is in turn, reflected on the number of seedlings established in each plot. The power of the analysis for the treatment effect on the model was 0.6, and the least significant number 30.47 for an alpha=0.05. Blocks had no significant effect on seedling establishment (p=0.7355), and interaction between the two factors was not significant (p=03613). Table shows the values for power details of the analysis. The greatest mean number of established

seedlings (46) was recorded in treatment 3 (No Shading, No Weeding), followed by treatment 4 (No Shading, Weeding). Here again, it seems that shading played an important role in these results. The two shaded treatments, 1 (Shading, Weeding) and 2 (Shading, No Weeding), showed the lowest mean number of seedlings established after one year (30 and 38.375, respectively) (Table 53). Comparison between the two highest means (treatments 3 and 4) showed that the difference was not statistically significant (p=0.8425), and neither was the difference between the two lowest means (1 and 2; p=0.1524) (Fig. 11). The difference, however, between these two groups of treatments (shaded x non-shaded) was significant (p=0.0114), showing that the results obtained for number of seedlings was mostly a reflection of the results already shown for germination, also confirming the importance of light in early stages of development of this palm species. On the other hand, there was no statistical difference between the treatments weeded and not weeded (p=0.2456), indicating that babassu seedlings are more successful in germinating in a sunny spot as compared to a weeded site.

Table 53. Descriptive statistics for number of seedlings established per treatment and block one year after planting.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	30.000	12.961	9-49	Block I	37.125	18.098	9-68
Treat.2	38.375	8.262	30-49	Block II	43.250	11.756	20-59
Treat.3	46.000	9.086	31-59	Block III	38.875	10.736	31-59
Treat.4	44.875	13.378	31-68	Block IV	40.000	8.912	30-53
Totals	39.812	10.921	9-68	Totals	39.812	12.275	9-59

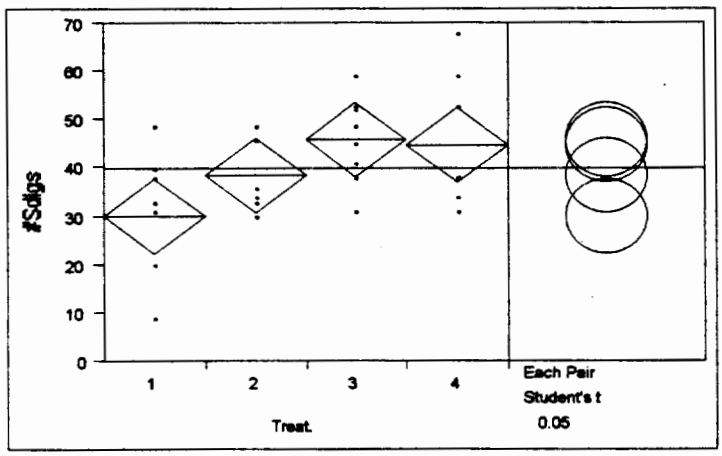
Table 54. Analysis of variance for number of seedlings one year after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	1298.125	432.708	3.483	0.0406*	0.2714
Blocks	3	159.625	53.208	0.428	0.7355	0.0333
Treat./Blocks	9	1337.125	148.569	1.196	0.3613	0.2795
Error	16	1988.000	124.250			0.4156
Total	31	4782.875				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	11.14675	6.369176	32	30.47146	0.6654
Blocks	0.0500	11.14675	2.233446	32	198.3317	0.1170
Treat.*Block	0.0500	11.14675	6.464144	32	56.72323	0.3887

Figure 11. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Number of Seedlings by Treatment



a.3) Leafing

Procedures - Since the main purpose was to measure biomass (leaf) production per treatment, the total number of leaves per plot was counted and averaged. The number of leaves per individual in the plot is here taken as the total number of leaves of all individuals in the plot by the number of individual seedlings. This was expected to provide a general idea of aerial biomass production per treatment, per season, per year, and for the entire period of the experiment.

Results - Leaf production was considerably higher in treatment 4 (No Shading, Weeding) with a mean of 102.12 leaves produced in those plots (Table 55). Germination, number of seedlings and number of leaves are directly related to each other and therefore, the results are practically the same obtained for the other two variables already shown. Treatment 3 (No Shading, No Weeding) followed treatment 4 with the second best mean number of leaves produced in the period (95.375), and again the shaded plots (treatments 1 and 2) were responsible for the lowest means in the experiment. Analysis of variance showed again an overall significant p-value for treatments, but not significant for blocks (p=0.2291) and for the possible crossing effects between both (p=0.7215). Table 56 shows the values for power and the least significant numbers for the effects tested on the model. Figure 12 provides a visual comparison for treatments. The interpretation here is basically the same: shading

inhibits germination, and consequently seedling production, which in turn results in a lower number of leaves produced per plot. Orthogonal comparisons revealed an expected situation, which can be summarized as follows: 1) no difference between treatments 3 and 4 with the highest means (p=0.6029); 2) statistical significance for the difference between 1 and 4 (p=0.0108); 3) no difference between the lowest means shown by 1 and 2 (p=0.2956); 4) the difference between the treatments with shading and with no shading is statistically highly significant (p=0.0097); and 5) treatments with weeding are not statistically different from those without weeding (p=0.7022).

Table 55. Descriptive statistics for number of leaves produced per treatment and block one year after the planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	65.500	29.320	21-103	Block I	74.250	36.421	21-141
Treat.2	79.250	15.988	54-96	Block II	101.125	27.068	42-125
Treat.3	95.375	18.814	65-122	Block III	81.375	23.706	58-131
Treat.4	102.125	31.831	58-141	Block IV	85.500	18.639	66-117
Totals	85.562	23.988	21-141	Totals	85.562	26.458	21-141

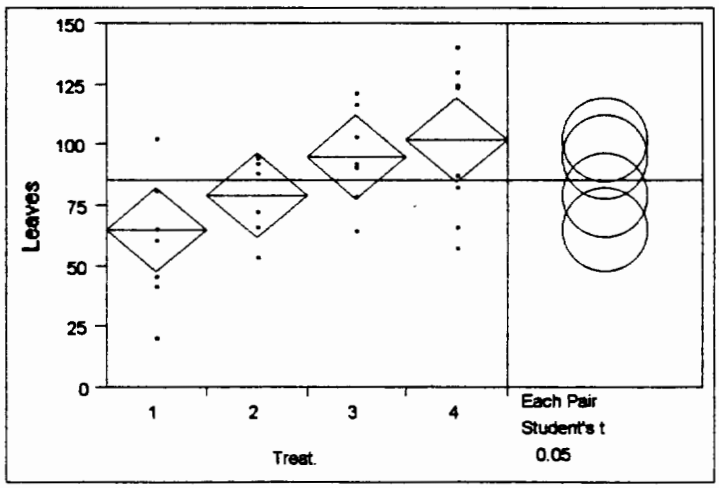
Table 56. Analysis of variance for number of leaves produced one year after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	6503.625	2167.875	3.350	0.0455	0.2723
Blocks	3	3101.625	1033.875	1.598	0.2291	0.1298
Treat./Blocks	9	3923.625	435.958	0.674	0.7215	0.1642
Error	16	10353.000	647.062			0.4335
Total	31	23881.875				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	25.43742	14.25617	32	31.26807	0.6467
Blocks	0.0500	25.43742	9.845089	32	56.761194	0.3400
Treat.*Block	0.0500	25.43742	11.07309	32	95..02227	0.2200

Figure 12. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Number of Leaves by Treatment



a.4) Growth

Procedures - Growth of seedlings was measured by the longest leaf of one of the seedlings if more than one seedling existed per seed. This measure, for a certain period of time, reflected the growth of the tallest seedling per seed until the establishment of the final seedling. The individual measures of seedlings were then averaged per treatment and analyzed.

Results - The overall effect of the non-shaded treatments that produced better responses in terms of germination, number of seedlings and leaf production, did not resulted in a concomitant increase in length (Table 57). Treatments and blocks had no significant effect on growth of seedlings (Table 58) at this point (p- values=0.1370 and 0.9448, respectively). Table shows the values for power and least significant number for the effects tested on the model. For treatments it can be noticed that power was low (0.4), although the least significant was not very far from the actual sample size: it shows that with a number of 44.29 observations for those given Alpha, Sigma and Delta we could have gotten a significant p-value for this analysis. The same is not true for blocks effect since the LSN was much higher (677.69). Although the means for treatments were not statistically different, they show slightly higher values for the treatments were weeding was not performed (treatments 2 and 3) (Table 57). Visual comparison of treatments is provided in Figure 13.

For this first year, the analysis of the recorded data reflected mostly the performance on germination, that in turn reflected on the other variables measured. As mentioned before, during up to ca. 12 months after germination, babassu seedlings still remain attached to the seed through the cotyledonary axis, and are partially fed by endosperm reserves. Therefore, a more accurate evaluation of the real behavior of babassu seedlings (especially that regarding growth) in degraded soils is more likely to be achieved after the detachment of seedlings from the seed, when they begin to grow and develop by exclusively using their young root system for absorbing soil nutrients. These overall results on growth of seedlings, however, showing no differences up to this point, confirm previous non-experimental observations on the extended attachment of the seedling to the seed, and the continued use of the endosperm reserves up to one year after the germination of the babassu seed.

Table 57. Descriptive statistics for length of seedlings (cm) per treatment and block one year after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	40.500	4.375	34-46	Block I	41.250	4.131	37-48
Treat.2	43.875	3.044	39-48	Block II	40.500	4.566	34-45
Treat.3	40.625	4.470	34-48	Block III	41.500	3.664	36-46
Treat.4	38.750	2.866	36-45	Block IV	40.500	4.472	36-48
Totals	40.938	3.688	34-48	Totals	163.75	4.208	34-48

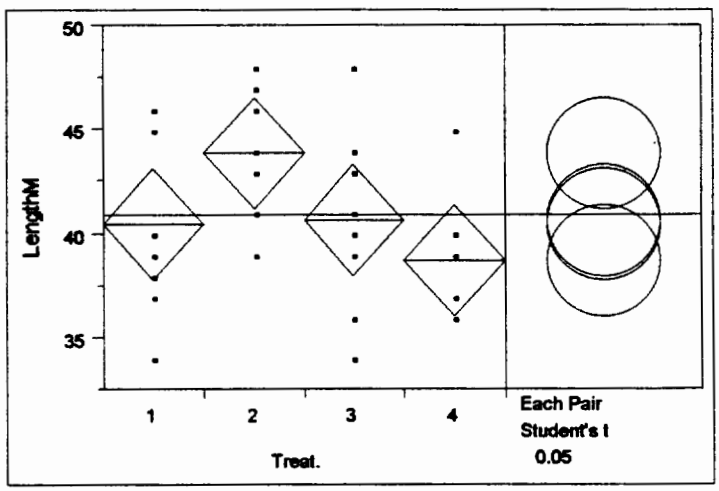
Table 58. Analysis of variance for length of seedlings (cm) one year after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	109.625	36.542	2.126	0.137	0.2167
Blocks	3	6.375	2.125	0.124	0.9448	0.0126
Treat./Blocks	9	114.875	12.764	0.743	0.667	0.2270
Error	16	275.000	17.188			0.5436
Total	31	505.875				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	4.145781	1.850887	32	44.29458	0.4420
Blocks	0.0500	4.145781	0.446339	32	677.6946	0.0679
Treat.*Block	0.0500	4.145781	1.894688	32	86.82717	0.2414

Figure 13. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Mean Length by Treatment



b) Second Census (August, 1991): 2.4 Years after Planting

b.1. Germination

After the second year, data was collected, including germination rates, the number of established seedlings, the total number of leaves , and the length of seedlings measured by the longest leaf (Table 59). These data indicate that the seeds continued to germinate during part of the second year, producing a slight alteration in the previous data recorded (a mean increase of 5.18 additional seed germinations/plot). With the additional germination, the overall percentage of germination reached the total of 80.96%, somewhat higher than the previous overall rate of 65.24%. This does not represent a considerable increase (166 seeds more than the number recorded in the one-year data), but it leads me to conclude that babassu seeds retain their viability for more than one year in field conditions. The overall mean germination rate was 26.71, but analysis of variance showed that there was no statistical difference among the means for each treatment (p=0.9643) (Table 60). Since this census was carried out 1.4 years after the previous one, it would be expected that no effect would be detected in the analysis since germination ceased ca. one year before and the differences among treatments were very small. It is possible that had a more significant effect on the germination of the last seeds as compared to the treatments themselves. Blocks produced an unexpected slightly significant effect on germination(p=0.0429), which is

difficult to explain. However, it may be related to the position of blocks in the area and the resulting different angles of light received. Interaction between treatments and blocks effects was not significant (p=0.6905).

Table 59. Descriptive statistics for number of seeds germinated per treatment and block 2.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	26.000			Block I	30.000		
Treat.2	27.000			Block II	28.375		
Treat.3	27.000			Block III	23.625		
Treat.4	26.875			Block IV	24.875		
Totals							

Table 60. Analysis of variance for number of seeds germinated 2.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	5.594	1.865	0.090	0.9643	0.0082
Blocks	3	211.844	70.615	3.419	0.0429	0.3113
Treat./Blocks	9	132.531	14.726	0.713	0.6905	0.1947
Error	16	330.500	20.656			0.4856
Total	31	680.469				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	4.544915	0.418097	32	926.9572	0.0629
Blocks	0.0500	4.544915	2.572959	32	30.84784	0.6564
Treat.*Blocks	0.0500	4.544915	2.035093	32	90.1685	0.2321

A similar situation was found for number of established seedlings and number of leaves produced, as would be expected since these numbers are partially a result of the number of seeds that germinated. However, there was a noticeable increase in the number of seedlings (mean increase of 7.12 seedlings) and total number of leaves (mean increase=66.78 leaves) during the past period of 1.4 years (monthly leafing rate per seedling=0.08) (Table 61); the mean number of leaves per seedling also jumped from 2.14 in the previous census to 3.24 (Table 63). Despite these mean increases, there was no statistical difference among the treatment means (p-values= 0.9609 and 0.5295, respectively for number of seedlings and leaves) (Table 62 and 64). These increased numbers are a good indication of the ability of babassu seedlings to overcome unfavorable conditions in their early phases of growth. Although treatments did not produce significant differences among their means, a noticeably higher increase in mean was obtained for both number of seedlings and leaves were obtained in those treatments with weeding, indicating that seedlings can benefit from this intervention. Blocks produced a significant effect on number of seedlings (p=0.0026), but not on number of leaves (p=0.0722). Interaction was not significant in both cases (p-values= 0.9033 and 0.7122, respectively for number of seedlings and leaves).

Table 61. Descriptive statistics for number of seedlings established per treatment and block 2.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	45.125	16.392	19-61	Block I	58.750	7.440	48-72
Treat.2	47.250	13.166	29-63	Block II	53.625	3.889	49-60
Treat.3	48.250	13.317	24-64	Block III	33.375	6.759	24-44
Treat.4	47.125	15.216	30-72	Block IV	42.000	17.088	19-64
Totals	46.938	14.522	19-72	Totals	46.938	8.794	19-72

Table 62. Analysis of variance for number of seedlings 2.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	41.125	13.708	0.096	0.9609	0.0068
Blocks	3	3140.625	1046.875	7.366	0.0026	0.5236
Treat./Blocks	9	542.125	60.236	0.424	0.9033	0.0903
Error	16	2274.000	142.125			0.3791
Total	31	5997.875				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	11.92162	1.133647	32	867.7409	0.0638
Blocks	0.0500	11.92162	9.906792	32	21.60885	0.9500
Treat.*Blocks	0.0500	11.92162	4.115994	32	147.3718	0.1470

Table 63. Descriptive statistics for number of leaves produced per treatment and block 2.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	153.875	45.599	93-220	Block I	173.875	45.028	139-275
Treat.2	137.750	35.419	90-198	Block II	175.500	42.848	111-229
Treat.3	147.375	38.913	78-203	Block III	123.625	32.802	78-181
Treat.4	170.375	61.307	94-275	Block IV	136.375	43.996	90-220
Totals	152.344	45.309	78-275	Totals	152.344	41.168	78-275

Table 64. Analysis of variance for number of leaves produced 2.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	4521.094	1507.031	0.766	0.5295	0.0698
Blocks	3	16636.594	5545.531	2.819	0.0722	0.2568
Treat./Blocks	9	12134.031	1348.226	0.685	0.7122	0.1873
Error	16	31471.500	1966.969			0.4859
Total	31	64763.219				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	44.35052	11.8863	32	112.7141	0.1778
Blocks	0.0500	44.35052	22.80117	32	35.37012	0.5646
Treat.*Blocks	0.0500	44.35052	19.47276	32	93.51487	0.2236

Mean length of seedlings increased considerably in the period of 1.4 years since the last census: it jumped from 40.93 cm to 52.23 cm (Table 65), an overall mean increase of 11.29 cm in the period, which represents a monthly growth rate per seedling of 0.7 cm. The major increases in the height of seedlings were recorded in treatments 2 and 3 (those with no weeding provided). Analysis of variance (Table 66) showed that treatment effect was highly significant (p=0.002), but no effect of blocks (p=0.8301) or interaction (p=0.8205) was detected in the analysis. The highest means were obtained in treatments 2 (56.9 cm) and 3 (56.0 cm). These two treatments (non-weeded plots), were statistically different (p=0.0003) from treatments 1 and 4 (weeded plots) which had the lowest means (50.27 cm and 45.75 cm, respectively). Visual comparison of treatments using Student's t tests is provided in Figure 14. The main effect here seems to be presence of other vegetation, what is the opposite of what one would expect . This may mean that in the early stage of development competition does not affect growth of the babassu seedling; on the contrary, the presence of other vegetation in the area may even favor it by maintaining higher moisture levels in contrast to weeded plots, even those shaded ones, where moisture can still evaporate more easily. This shows that with the competitive vegetation at the same level of development, babassu seedlings are able to keep up with relatively high growth rates by taking advantage of the higher moisture content in these areas. This is confirmed by observing that the third highest mean obtained in this census was recorded for treatment 1 (50.27 cm), a weeded plot, where the babassu seedling could take advantage of shading as a factor

for maintenance of a fair moisture level in the soil. Growth performance dropped dramatically in treatment 4 (No Shading, Weeding), where seedlings were growing under direct sunlight. The difference between this treatment and the other three was highly significant (p=0.0010). The analyses to be presented, show how long babassu seedlings are able to cope with competition in higher moisture levels of the non-weeded plots, and still maintain growth rates at reasonable levels.

Seedling development during the second year does not appear to be directly related to the growth in length; it seems that the production of green mass (leaf) for photosynthetic activity is the priority for the babassu seedling, at least during its early development.

Table 65. Descriptive statistics for length of seedlings (cm) per treatment and block 2.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	50.275	6.879	38.9-60.4	Block I	52.287	6.086	43.6-62
Treat.2	56.900	2.767	53.6-60.8	Block II	52.700	7.886	38.9-60.8
Treat.3	56.000	3.340	50.1-62	Block III	53.137	6.779	38.6-60.4
Treat.4	45.750	4.647	38.6-50.5	Block IV	50.800	5.703	39.7-56.4
Totals	52.231	4.408	38.6-62	Totals	52.231	6.613	38.6-62

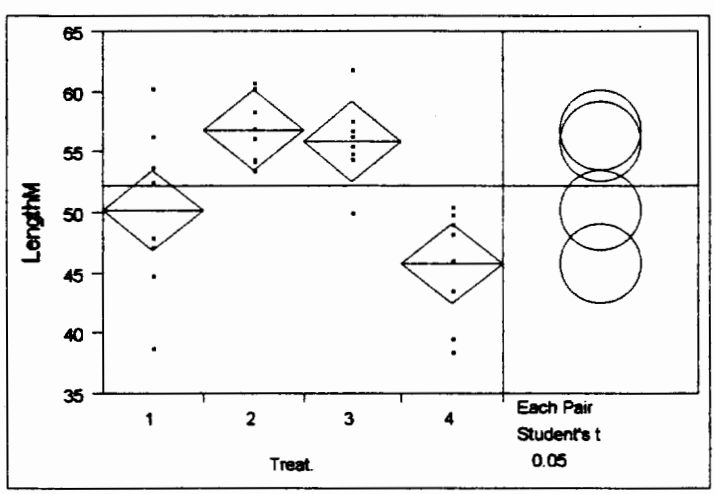
Table 66. Analysis of variance for length of seedlings (cm) 2.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	654.674	218.225	7.743	0.002	0.5159
Blocks	3	24.741	8.247	0.293	0.8301	0.0194
Treat./Blocks	9	138.474	15.386	0.546	0.8205	0.1091
Error	16	450.960	28.185			0.3554
Total	31	1268.849				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	5.308955	4.523113	32	21.32447	0.9594
Blocks	0.0500	5.308955	0.879287	32	288.4688	0.0943
Treat.*Block	0.0500	5.308955	2.080217	32	115.7784	0.1815

Figure 14. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Length byTreatment



c) Third Census (January, 1992): 2.9 Years after Planting

The results obtained in this third general collection of data are shown in Table. Data was taken in January, 1992, 5 months after the previous census. The data recorded in this collection have a particular importance as they may reflect the behavior of seedlings after the dry period (July - December). The dry season clearly affected the experiment, which shows death of many seedlings, an overall decrease of the number of leaves and the maintenance of the length of plants at almost the same levels as recorded five months before. Germination of seeds was no longer recorded and the number of dead plants was very variable throughout all treatments in all blocks. I believe that from this point on, the plants demonstrate their ability for establishment in degraded soils, competing more aggressively, in different conditions, for the nutrients and light they need for growth and biomass production.

The overall mean number of seedlings decreased from 46.938 to 37.531 (Table 67) . This indicates that excess number of seedlings have gradually been eliminated; the more resilient seedlings survived, and the dry season seemed to select for the strongest seedlings. The highest number of seedlings was eliminated in those treatments where shading and weeding were not provided (treatment 4) with a mean decrease of 11.250 seedlings; this suggests that the primary competition was not for nutrients, but for water. Treatment 2 had the second highest decrease in number of

seedlings (10.0), showing that after the competition for moisture, nutrients play the next crucial role in the elimination of the excess of seedlings. The mean number of seedlings (37.531) came very close to the expected mean number per plot (33). From this point on, the babassu seedlings in the plots begin to compete with other plant species rather than their own.

The total mean number of leaves produced in the period (128.218) decreased in comparison to the last census (152.344) as the result of the decrease in the number of seedlings (Table 69). However, the mean number of leaves per seedling increased from 3.24 to 3.41, showing that the seedlings produced few new leaves. Analysis of variance showed no significant effect of treatments on both number of seedlings and leaves produced (p=0.8301 and 0.9536, respectively). The analysis detected a significant effect of blocks on number of seedlings (p=0.0225), but not on number of leaves ((p=0.1011); no interaction of effects was detected (p=0.8148 and 0.3547, respectively for number of seedlings and leaves). Although the differences were not statistically significant, the highest number of seedlings and leaves continued to be recorded in the treatments where shading was directly or indirectly provided. The treatment under direct sunlight had the lowest number of seedlings and leaves after the dry period. The results of the analyses of variance for number of seedlings and leaves are shown in Tables 68 and 70.

Table 67. Descriptive statistics for number of seedlings established per treatment and block 2.9 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	37.125	9.862	19-52	Block I	39.000	4.567	32-45
Treat.2	37.250	9.223	26-53	Block II	45.500	5.682	38-53
Treat.3	39.875	11.012	21-54	Block III	30.375	5.630	21-39
Treat.4	35.875	8.219	25-48	Block IV	35.250	12.510	19-54
Totals	37.531	9.579	19-54	Totals	37.531	7.097	19-54

Table 68. Analysis of variance for number of seedlings 2.9 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	67.844	22.615	0.293	0.8301	0.0254
Blocks	3	976.594	325.531	4.212	0.0225	0.3663
Treat./Blocks	9	385.031	42.781	0.554	0.8148	0.1444
Error	16	1236.500	77.281			0.4638
Total	31	2665.969				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	8.790975	1.456062	32	288.4478	0.0943
Blocks	0.0500	8.790975	5.52436	32	27.14013	0.7557
Treat.*Blocks	0.0500	8.790975	3.46875	32	114.2575	0.1838

Table 69. Descriptive statistics for number of leaves produced per treatment and block 2.9 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	127.250	33.669	78-173	Block I	143.250	25.532	107-184
Treat.2	129.250	59.329	70-248	Block II	150.000	47.171	93-248
Treat.3	133.875	47.103	56-211	Block III	102.000	31.245	56-150
Treat.4	122.500	33.316	77-184	Block IV	117.219	49.908	70-211
Totals	128.219	43.354	56-248	Totals	128.219	38.464	56-248

Table 70. Analysis of variance for number of leaves produced 2.9 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	533.594	177.865	0.109	0.9536	0.0094
Blocks	3	12000.094	4000.031	2.450	0.1011	0.2127
Treat./Blocks	9	17754.281	1972.698	1.208	0.3547	0.3147
Error	16	26121.500	1632.594			0.4630
Total	31	56409.469				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	40.40537	4.083479	32	768.5967	0.0657
Blocks	0.0500	40.40537	19.36499	32	39.43582	0.5013
Treat.*Blocks	0.0500	40.40537	23.55464	32	56.21599	0.3928

After this 6-month dry period, seedlings showed a few slight changes in terms of growth (Table 71). The increase in the overall mean length of seedlings was only 1.39 cm which corresponds to a monthly growth rate of 0.28 cm per seedling, much lower that for the previous period. Treatments continued to produce an overall significant effect on growth (p=0.0130), as shown by the results of the analysis of variance (Table 72). No significant effect of blocks (p=0.7727) and interaction (0.7249) was detected. Again, the best growth rates were recorded in treatments 2 (Shading, No Weeding; mean=57.75 cm) and 3 (No Shading, No Weeding; mean=57.125 cm). However, it is important to point out that the better performance of those two treatments is still a result of the better growth performance before the past dry season. This can be seen by observing the mean increases for each treatment and the highest increase was that obtained for treatment 1 (Shading, Weeding; mean increase= 2.975 cm); the other treatments had their means very close to those recorded previously. It means that in times of water scarcity, shading (by retaining moisture) and weeding (by reducing competition for water), combined, produce a very beneficial effect on the growth of babassu seedlings. Figure 15 provides a visualization of treatments using Student's t tests.

Contrast between the two highest means (treatments 2 and 3) showed no difference between them (p=0.8534). Neither there was significant difference between treatments 1 and 2), and 1 and 3. However, there was a significant difference between the lowest

mean (treatment 4) and the other three (p=0.0026), showing that most of the variance and overall significance for treatment effect was produced in a negative way by the absence of shading and weeding combined. In dry times shading made a difference: first, in the non-weeded plots (2 and 3) where the presence of other vegetation provided the shading for keeping moisture in the plot; second, in the plot where shading was directly provided as a treatment (1), and where the highest increase was recorded for this dry period. Up to this point of development, the babassu seedlings have been able to overcome the presence of competition by taking advantage of the higher levels of moisture in these plots; weeding had a beneficial effect on growth only when shading was provided.

Table 71. Descriptive statistics for length of seedlings (cm) per treatment and block 2.9 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	53.250	8.647	40-66	Block I	52.125	4.642	44-59
Treat.2	57.750	4.166	52-64	Block II	55.250	10.194	40-64
Treat.3	57.125	4.189	52-64	Block III	54.375	8.158	38-66
Treat.4	46.375	6.069	38-55	Block IV	52.750	6.408	41-60
Totals	53.625	5.767	38-64	Totals	53.625	7.350	38-66

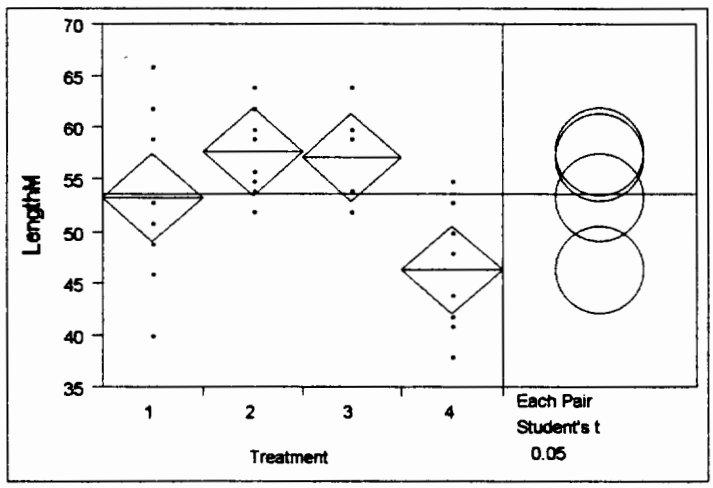
Table 72. Analysis of variance for length of seedlings (cm) 2.9 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	655.750	218.583	4.933	0.013	0.3899
Blocks	3	49.750	16.583	0.374	0.7727	0.0295
Treat./Blocks	9	267.000	29.667	0.669	0.7249	0.1587
Error	16	709.000	44.312			0.4216
Total	31	1681.500				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	6.656763	4.52683	32	25.02684	0.8248
Blocks	0.0500	6.656763	1.246871	32	226.3828	0.1078
Treat.*Block	0.0500	6.656763	2.888555	32	95.58545	0.2187

Figure 15. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Length by Treatment



d) Fourth Census (July, 1992): 3.3 Years after Planting

The fourth general collection of data was carried out in July 1992, 3.3 years after the experiment was installed and 6 months following the previous collection. These data were collected at the end of the rainy season and were expected to reflect the effects of the availability of moisture in the period, in contrast with the period previously discussed.

A small decrease in the number of established seedlings made the actual mean number (35.21) approach the expected number per plot (33) (Table 73). All treatments got very close to the ratio of 1 seedling per seed planted, as expected. The plots with shading provided were those where the highest numbers of excess seedlings (above 33) were recorded in the previous census, and therefore, these were the treatments with the highest number of seedlings that died in this period. When moisture was not the limiting factor, the overall vigor and ability to absorb and use the scarce nutrients in the soil may then become the most important factor of effect on seedling survival.

Effect of treatments was not statistically significant (p=0.6853), and blocks once again maintained a significant p-value (0.008), showing that the continued difference among the blocks persisted up to this point (Table 74). It cannot be taken as an effect,

since no additional differences in the number of seedlings per plot were produced. Interaction between blocks and treatments did not significantly exist (p=0.5837).

Table 73. Descriptive statistics for number of seedlings established per treatment and block 3.3 years after planting.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	32.250	8.940	19-49	Block I	44.500	8.960	30-55
Treat.2	35.500	10.583	23-53	Block II	36.000	4.869	29-44
Treat.3	36.750	10.740	19-54	Block III	29.000	5.014	19-34
Treat.4	36.375	8.830	28-55	Block IV	31.375	10.500	19-49
Totals	35.219	9.773	19-55	Totals	35.219	7.335	19-55

Table 74. Analysis of variance for number of seedlings 3.3 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	100.594	33.531	0.504	0.6853	0.0359
Blocks	3	1121.594	373.865	5.614	0.008	0.4009
Treat./Blocks	9	509.781	56.642	0.851	0.5837	0.1822
Error	16	1065.500	66.594			0.3808
Total	31	2797.469				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	8.160499	1.773007	32	169.2795	0.1300
Blocks	0.0500	8.160499	5.920288	32	23.66035	0.8744
Treat.*Blocks	0.0500	8.160499	3.991324	32	76.6843	0.2758

Biomass (leaves) produced during this period showed a considerable overall increase (Table 75) in contrast with the previous period when leaf biomass decreased due to seedling mortality. The mean number of leaves increased by 23.469, representing a mean increase of 3.91 per month per plot, and a monthly rate per seedling of 0.11 leaves produced. The number of leaves per seedling increased from 3.41 recorded six months before to 4.30 in this post-rainy season period. Analysis of variance showed no difference among treatments and blocks or a combined effect of both (p-values=0.8563, 0.1748, and 0.655, respectively) (Table 76). Leafing seems to be follow a very stable phenological pattern with very little or no variation at all throughout the year, or even between seasons. Although the differences among treatments were not statistically significant, it was noted that the highest increases in number of leaves produced during the last six months was in shaded plots (treatments 1 and 2), whether weeded or not. Our interpretation of this was that the photosynthetic leaf area of the seedlings (including number of leaves) must increase in shaded conditions, in order to better absorb the less incident sunlight on the seedling leaves, due to the surrounding taller vegetation.

Table 75. Descriptive statistics for number of leaves produced per treatment and block 3.3 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	158.875	48.096	84-246	Block I	171.125	31.988	137-232
Treat.2	155.875	62.279	64-246	Block II	170.125	37.429	129-246
Treat.3	152.500	40.977	71-204	Block III	123.625	43.762	64-184
Treat.4	139.500	37.298	86-202	Block IV	141.875	57.811	84-246
Totals	151.688	47.162	64-246	Totals	151.688	42.747	64-246

Table 76. Analysis of variance for number of leaves produced 3.3 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	1747.125	582.375	0.255	0.8563	0.0262
Blocks	3	12812.375	4270.792	1.873	0.1748	0.1924
Treat./Blocks	9	15548.375	1727.597	0.758	0.655	0.2335
Error	16	36475.000	2279.688			0.5478
Total	31	66582.875				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	47.74607	7.389023	32	329.8646	0.0883
Blocks	0.0500	47.74607	20.00967	32	49.33908	0.3938
Treat.*Blocks	0.0500	47.74607	22.04284	32	85.22198	0.2462

The mean increase in length (6.81 cm) for this six-month period was significantly higher than for the previous one (1.39 cm). A higher increase in monthly growth rate was consequently recorded (1.13 cm). This is a reflection of water available to the seedlings during this period. The growth rate per seedling for the period was 0.193 cm in contrast with that recorded for the dry period of 0.037 cm. The monthly growth rate per seedling, per month was 0.033 cm. Table 77 provides the descriptive statistics for length of seedlings for this period.

Table 78 shows the results of the analysis of variance of the data pertaining to this period. The results of the treatments were significantly different in growth means (p=0.0239); blocks had no effect on the model (p=0.9232), and no interaction of effects was detected (p=0.4484). Best growth performances were maintained by those treatments where shading was provided, either directly (as for treatments 1 and 2), or indirectly (as for treatment 3), where non-weeding now is producing a confounding effect with shading. In those non-weeded plots the successional vegetation has grown to a height that produces shading over the shorter babassu seedlings, and therefore, this is confounded now with the effect of shading directly applied as a treatment in all non-weeded plots. From this point on, the differences in these plots will reflect primarily competition for soil resources, rather than the absence of shading in the non-weeded plots. There was no significant difference among these three treatments (p-values?); statistical difference only existed when treatment 4 was compared to each of the other

three, both individually or as a group. This shows that direct sunlight has a negative (or delaying) effect on growth of babassu seedlings up to this stage. The highest mean increase was recorded in treatment 1, showing a very beneficial effect of shading in combination with weeding. This result is the satisfactory development of seedlings with significant biomass (leaf) production. This experimental observation is consistent with the observation of this species' behavior in nature. Table 78 shows the power details for this analysis. Figure 16 provides a visual comparison of treatments.

Table 77. Descriptive statistics for length of seedlings (cm) per treatment and block, 3.3 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	63.262	14.035	46.1-84.9	Block I	58.550	6.403	47.2-66.8
Treat.2	63.162	2.424	59-66.8	Block II	61.463	12.732	46.4-86.1
Treat.3	64.912	9.391	55.7-86.1	Block III	61.175	11.230	41.5-76.8
Treat.4	50.425	5.703	41.5-58.1	Block IV	60.575	11.979	46.1-84.9
Totals	60.441	7.888	41.5-86.1	Totals	60.441	10.586	41.5-86.1

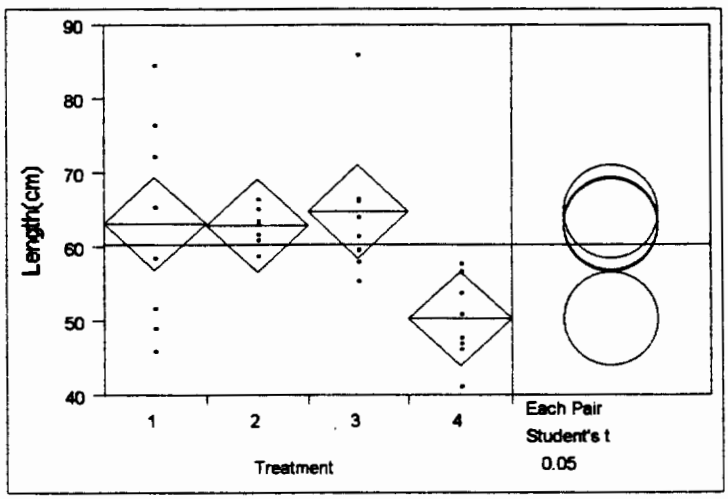
Table 78. Analysis of variance for length of seedlings (cm), 3.3 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	1085.456	361.819	4.134	0.0239	0.3239
Blocks	3	41.408	13.803	0.158	0.9232	0.0123
Treat./Blocks	9	823.488	91.499	1.045	0.4484	0.2457
Error	16	1400.365	87.523			0.4179
Total	31	3350.717				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	9.355363	5.824131	32	27.42817	0.7470
Blocks	0.0500	9.355363	1.137547	32	532.0664	0.0730
Treat.*Block	0.0500	9.355363	5.072868	32	63.75538	0.3394

Figure 16. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Length(cm) by Treatment



e) Fifth Census (December, 1993): 4.8 Years after Planting

These data were collected 1.5 years after the previous census, and following a dry season which ended in December; again, the data appear to reflect that situation. During the 18 month period since the previous census, the mean number of established seedlings remained stable, with no seedling death recorded (Table 79). This is an important observation, as it shows that the established seedlings were able to come through two dry seasons and one rainy season without dying. More important, yet, is that treatments did not produce significant differences on the number of seedlings, confirming the expected resilience of this palm species.

Analysis of variance did not show a significant p-value (0.3172) for treatments on the number of seedlings; blocks again were statistically significant (p-value=0.0024); and, no interaction between effects was detected by the analysis (p=0.4096) (Table 80). Although the differences among treatments were not significant, it is noteworthy to mention that once more the highest means were recorded in those treatments where no weeding was applied, followed by treatment 1, where weeding was applied but so was shading. This repeats what we have seen in the previous analyses: the major effect seems to be produced by shading, which at this point of the experiment comes both from the shading applied to plots directly and from those non-weeded treatments, indirectly.

Table 79. Descriptive statistics for number of seedlings established per treatment and block 4.8 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	34.375	4.926	26-43	Block I	43.500	5.345	36-54
Treat.2	37.625	14.070	21-57	Block II	40.875	7.827	32-57
Treat.3	39.750	5.946	29-48	Block III	29.750	6.734	20-38
Treat.4	33.750	9.361	19-42	Block IV	31.375	8.798	19-45
Totals	36.375	8.575	19-57	Totals	36.375	7.176	19-57

Table 80. Analysis of variance for number of seedlings 4.8 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	190.750	63.583	1.273	0.3172	0.0730
Blocks	3	1119.250	373.083	7.471	0.0024	0.4292
Treat./Blocks	9	498.500	55.389	1.109	0.4096	0.1911
Error	16	799.000	49.938			0.3064
Total	31	2607.500				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	7.06647	2.441503	32	69.78048	0.2759
Blocks	0.0500	7.06647	5.914099	32	21.52576	0.9528
Treat.*Blocks	0.0500	7.06647	3.946913	32	60.53341	0.3603

Analysis of variance showed exactly the same situation for number of leaves produced (Table 82). No significance for treatment effect (p=0.3261), a significant effect of blocks (p=0.0068), and no interaction between effects (0.9824). However, although the number of seedlings remained the same throughout 18 months, number of leaves decreased (Table 81) in comparison with the last census, from 4.30 leaves per seedling to 3.85; this represents a mean decrease of 0.45 leaves per seedling. The overall mean number of leaves produced in the plots decreased from 151.688 in the last census to 140.156 in this census; the highest losses of leaves occurred in the non-weeded treatments (2 and 3), with a much smaller number of leaves lost in the weeded treatments (1 and 4). This shows that during stressful times, as in the dry season, competition has a strong effect on the seedlings, which is in turn reflected on the number of leaves produced, significantly reduced. At this point, the beneficial effect of shading and maintenance of a higher moisture level by the surrounding vegetation no longer existed. Seedlings began to react to the effect of the competition, shown by the decrease in the number of leaves. This number would be expected to increase in order to be able to absorb more efficiently the scarce sunlight in the understory of the successional stands. Climatic factors (especially rainfall and light) may have had a strong effect on these results.

Table 81. Descriptive statistics for number of leaves produced per treatment 4.8 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	156.000	28.086	125-198	Block I	172.500	20.227	138-198
Treat.2	128.375	29.760	78-174	Block II	147.625	25.286	110-178
Treat.3	136.250	32.631	86-181	Block III	118.500	30.561	57-150
Treat.4	140.000	41.015	57-187	Block IV	122.000	27.018	78-152
Totals	140.156	32.873	57-198	Totals	140.156	25.773	57-198

Table 82. Analysis of variance for number of leaves produced 4.8 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	3240.844	1080.281	1.246	0.3261	0.0947
Blocks	3	15204.344	5068.115	5.844	0.0068	0.4446
Treat./Blocks	9	1870.531	207.837	0.240	0.9824	0.0547
Error	16	13876.500	867.281			0.4058
Total	31	34192.219				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	29.44964	10.06362	32	71.21157	0.2704
Blocks	0.0500	29.44964	21.79761	32	23.29432	0.8881
Treat.*Blocks	0.0500	29.44964	7.645528	32	256.2504	0.0999

Growth increased during this period, but not significantly (p=0.0602), indicating that treatments did not affect growth performance of the seedlings; neither did blocks (p=0.8449), and no interaction existed between the effects tested (p=0.8177). There were no differences among the means for growth (Table 84). It seems that at this point, the seedlings reached a stable growth rate that was not affected by the treatments, or even by the shortage of rainfall in the dry season. Reduction of the number of leaves produced during the dry period may have been a biological strategy used by the seedlings: a higher investment was made in growth rather than in leafing, since the competing vegetation was taller, which could result in difficulties of development for the seedlings. Table 83 and Figure 17 show the means for treatments; it can be noticed that treatment 1 was higher than the others, but that difference was not significant enough to be detected by the analysis. However, the overall p-value for treatment effect was very close to the significance level (0.05). Although the power value was not high (0.5977), the least significant number (33.58538) was not far from the actual number used in the experiment (32). This means that the not significant result for treatment effect could have changed with a somewhat higher sample size; and, probably there would be a significant difference between treatment 1 and the other three. Still, the results show the resilience of the babassu seedlings under the different treatments applied, although it appears that they can benefit from shading and weeding.

Table 83. Descriptive statistics for length of seedlings (cm) per treatment and block 4.8 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	98.819	21.791	65.01-125.1	Block I	73.094	14.096	60-15-97.8
Treat.2	72.071	10.519	59.12-87.6	Block II	77.253	15.449	65.28-110.44
Treat.3	69.704	10.253	59.8-89.5	Block III	82.749	27.632	43.4-125.1
Treat.4	72.518	29.389	42.3-135.8	Block IV	80.016	30.715	42.3-135.8
Totals	78.278	17.988	42.3-135.8	Totals	78.278	21.973	42.3-135.8

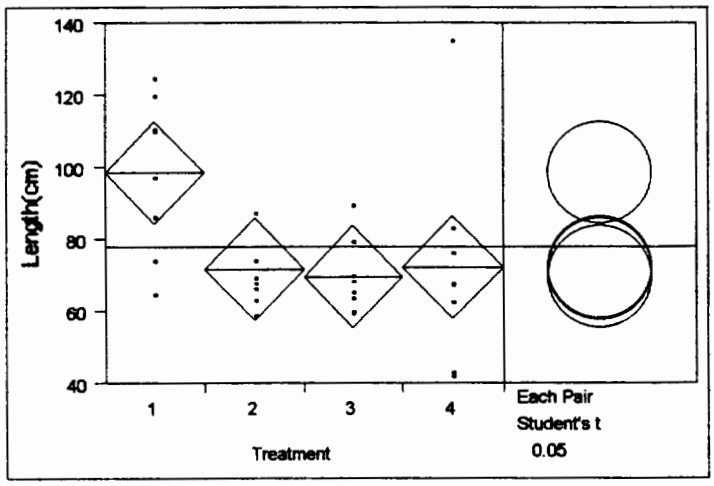
Table 84. Analysis of variance for length of seedlings (cm) 4.8 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	4537.178	1512.393	3.025	0.0602	0.2942
Blocks	3	407.498	135.833	0.272	0.8449	0.0264
Treat./Blocks	9	2473.383	274.820	0.550	0.8177	0.1604
Error	16	8000.054	500.003			0.5188
Total	31	15418.113				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	22.36075	11.90743	32	33.58538	0.5977
Blocks	0.0500	22.36075	3.568516	32	310.4161	0.0909
Treat.*Block	0.0500	22.36075	8.791656	32	115.0321	0.1826

Figure 17. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Length(cm) by Treatment



f) Sixth Census (August, 1994): 5.4 Years after Planting

After a period of 5.4 years since its installation in 1989, the experiment was concluded. Up to this point, only non-destructive measurements had been made for collection of information on germination, number of seedlings, number of leaves produced, and growth rate. Photos 22- 28 (Apendix I) show aspects of the treatments and seedlings at the end of the experiment. For this final census, however, destructive measurements were made in order to obtain information on additional characters such as fresh and dry weight of leaves and roots. Seedlings were counted and dug out of the soil , the leaves counted, plant parts cut and weighed in the field to obtain fresh weight data (Photos 29 - 31, Apendix I). The plant material was then placed in separate paper bags and dried for 48 hours (leaves) to 72 hours (rhizome-roots) at temperature of ca. 70°C. After drying, the material was re-weighed.

Number of Seedlings. This last collection of data yield a surprise regarding the number of seedlings in the experimental plots. In the last census it was found that the number of established seedlings had achieved a stability, and no variation on that number was recorded. It seemed at that time, that selection brought the number of seedlings to ratio of 1 seedling per seed, expected since the babassu palm is not a clustering species. Given the environmental difficulties of the area plus the treatments applied, one could expect that competition between seedlings sharing the same spot would cause the death of the less-fit

seedlings. This was especially noticeable following the dry season, when the number of seedlings was reduced to the point where stability was thought to have been achieved. However, this last data collection proved that notion to be wrong: the "dead" seedlings in fact did not die. What seems to have happened is that the seedlings that disappeared and consequently, were not counted during two census, only lost their aerial part, but kept the apical meristem alive, underground. With more favorable conditions, those seedlings were again able to retake growth and production of new leaves. This seems logical, since it explains in part the aggressiveness of this palm species as a colonizer, succeeding where other plant species fail. The difference in the number of seedlings was not big, however, only 9 seedlings "reappeared". An alternative explanation for this increase in the number of seedlings may be a miscounting of during one of the censuses, but this would require the mistake to be made more than once, which we do not think is likely.

This new situation increased the overall mean for number of seedlings (44.59) in contrast to the mean obtained 8 months before (36.37) (Table 85). The highest number of seedlings "reappeared" in those treatments where shading was provided, directly (1) or indirectly (2 and 3). In contrast, in treatment 4, with shading and weeding, the number of seedlings was reduced slightly in comparison with the previous number recorded. This seems to support the "reappearance" hypothesis of viable underground apical meristems in seedlings without leaves. Analysis of variance, however, did not detect difference among the means (Table) for treatment effect (p=0.2674), although blocks had a significant effect

(p=0.0049); no interaction between the effects tested was detected by the analysis (p=0.2582) (Table 86).

Table 85. Descriptive statistics for number of seedlings established per treatment 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	42.625	9.349	29-57	Block I	52.625	11.083	42-75
Treat.2	48.750	19.241	24-75	Block II	52.750	9.676	43-68
Treat.3	47.750	12.691	24-64	Block III	36.625	9.241	24-52
Treat.4	39.250	11.597	18-52	Block IV	36.750	14.831	18-59
Totals	44.594	13.219	18-75	Totals	44.594	11.207	18-75

Table 86. Analysis of variance for number of seedlings 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	477.344	159.115	1.443	0.2674	0.0830
Blocks	3	2096.594	698.865	6.337	0.0049	0.3646
Treat./Blocks	9	1411.281	156.809	1.422	0.2582	0.2454
Error	16	1764.500	110.281			0.3068
Total	31	5749.719				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	10.50149	3.862252	32	62.23046	0.3094
Blocks	0.0500	10.50149	8.094353	32	22.62663	0.9132
Treat.*Blocks	0.0500	10.50149	6.640974	32	49.03039	0.4618

Number of Leaves. This increased considerably in the last eight months: from an overall mean of 140.15 to 219.81 (a mean increase of 79.65 for the period) (Table 87). The mean number of leaves per seedling also increased from 3.85 to 4.92, which represents a mean increase of 1.07 leaves/seedling. The monthly leafing rate computed was 0:133 (?), higher (lower) than the previous one recorded (dry/rainy season comparison). The major increases in leaf production were obtained in the non-weeded treatments (2 and 3), showing how the presence of the surrounding vegetation may favor this character during the rainy season (compare to the other rainy season). The lowest increases were computed for the weeded treatments (1 and 4), particularly for treatment 4, where shading was not applied. However, again analysis of variance showed no difference among the treatment means (p=0.7379), and once again a significant effect of blocks on leaf production was recorded (p=0.0068); interaction between effects was not significant (p=0.4611) (Table 88).

Table 87. Descriptive statistics for number of leaves produced per treatment and block 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	218.250	45.455	136-292	Block I	256.875	51.954	193-354
Treat.2	234.875	98.313	85-354	Block II	270.000	48.544	228-339
Treat.3	224.000	70.648	109-336	Block III	177.375	52.314	94-249
Treat.4	202.125	68.865	94-286	Block IV	175.000	74.233	85-292
Totals	219.812	70.820	85-354	Totals	219.812	56.761	85-354

Table 88. Analysis of variance for number of leaves produced 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	4477.625	1492.542	0.425	0.7379	0.0289
Blocks	3	61612.125	20537.375	5.845	0.0068	0.3981
Treat./Blocks	9	32430.125	3603.347	1.026	0.4611	0.2095
Error	16	56215.000	3513.438			0.3632
Total	31	154734.875				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	59.27426	11.82902	32	199.8995	0.1164
Blocks	0.0500	59.27426	43.87914	32	23.29176	0.8882
Treat.*Blocks	0.0500	59.27426	31.83459	32	64.84211	0.3329

Growth of Seedlings. The mean increase for this eight-month period since the last census was 19.72 cm, which represents a mean growth rate of 0.44 cm per seedling . The best performances were recorded in treatments 2 and 3 (non-weeded) (Table 89), and surprisingly, the lowest mean increase in growth were computed for treatments 1 and 4 (the two weeded treatments), a result completely different from the previous one. It confirms then, a pattern: in the dry season, weeding favors growth of babassu seedlings because of the lack of competition for the scarce moisture in the soil, but when water is not a limiting factor during the rainy season, the competition with the other vegetation does not seem to be a problem for the seedlings, and growth happens at a fair rate, in contrast with that in the

weeded plots where growth seems to be delayed. Therefore, at this developmental point, the growth rate of babassu seedlings seems to be more affected by competition for moisture than for nutrients. The means for treatments were not significantly different from each other (p=0.2608), as shown by the analysis of variance (Table 90), which also shows no significance for blocks, and, more surprisingly, a statistical significant interaction between treatments and blocks (p=0.0044).

Table 89. Descriptive statistics for length of seedlings (cm) per treatment and block 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	107.212	29.343	78.9-147.0	Block I	90.462	11.642	70.8-108.1
Treat.2	96.850	11.366	79-114.9	Block II	96.350	19.154	76.2-129.4
Treat.3	96.875	11.548	87.1-118.7	Block III	102.000	31.220	53-147.0
Treat.4	91.075	31.240	53-149.3	Block IV	103.200	25.690	78.9-149.3
Totals	98.003	20.874	53-149.3	Totals	98.003	21.926	53-149.3

Table 90. Analysis of variance for length of seedlings (cm) 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	1083.311	361.104	1.468	0.2608	0.0686
Blocks	3	820.611	273.537	1.112	0.3733	0.0520
Treat./Blocks	9	9940.813	1104.535	4.491	0.0044	0.6299
Error	16	3935.515	245.970			0.2493
Total	31	15780.250				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	15.68342	5.818373	32	61.25764	0.3144
Blocks	0.0500	15.68342	5.064000	32	79.13807	0.2442
Treat.*Block	0.0500	15.68342	17.62528	32	24.05313	0.9610

Fresh and Dry Weight of Leaves. While treatments did not have a significant effect on the number of leaves produced, it did have a highly significant effect on the weight of leaves (p-values=0.0009 and 0.0001, respectively for fresh and dry weight); blocks had no significant effect in both cases (p-values=0.6601 and 0.1889), while interaction of effects could only be detected for the dry weight (p=0.0079). Tables 91 - 94 show the descriptive statistics and the results of the analysis of variance performed for both fresh and dry weight. In both cases, the highest means were obtained in the weeded treatments 1 and 4, which shows that the overall better performance in growth was a result of the better absorption, use and accumulation of nutrients. Comparisons between these two treatments showed no statistical difference (p=0.0966) for fresh weight, but there was a slightly significant difference between them when dry weight was analyzed (p=0.0209). In both cases, the weeded treatments were significantly superior in terms of weight of biomass (leaves) produced; these treatments compared to non-weeded treatments showed a highly significant difference (p-values= 0.0001 and <0.0001, respectively for fresh and dry weight), confirming that weeding has a positive effect on leaf biomass. For both fresh and dry weight of leaves, contrast between treatments 2 and 3 showed that the difference was not significant (p-value for fresh weight=0.9374; p-value for dry weight=0.8219). On the other hand, comparison between treatments 2 and 4 showed a significant difference between them (p-values=0.020 and 0.004, respectively for fresh and dry weight of leaves). Visual comparisons of the means for fresh and dry weight of leaves by treatments are shown in Figures 18 and 19.

These results show that while the treatments did not produce differences in terms of number of leaves, they did account for a significant difference among the means for fresh and dry weight of leaves. The weeded treatments, where the seedlings did not have the competition of the successional vegetation did much better in terms of the weight of the biomass produced.

Table 91. Descriptive statistics for fresh weight of leaves (Kg) per treatment and block 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	7.445	4.694	2.3-15.6	Block I	4.691	3.668	1.91-12.5
Treat.2	2.084	0.825	0.42-3.05	Block II	3.519	1.995	2-8.1
Treat.3	1.985	0.793	0.96-3.2	Block III	4.796	5.160	0.75-15.6
Treat.4	5.259	2.757	0.75-9.2	Block IV	3.766	3.081	0.42-9.2
Totals	4.193	2.267	0.42-15.6	Totals	4.193	3.476	0.42-15.6

Table 92. Analysis of variance for fresh weight of leaves (Kg) 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	168.284	56.095	9.139	0.0009	0.4371
Blocks	3	9.991	3.330	0.543	0.6601	0.0259
Treat./Blocks	9	108.493	12.055	1.964	0.1145	0.2818
Error	16	98.209	6.138			0.2551
Total	31	384.977				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	2.477506	2.293225	32	20.53322	0.9818
Blocks	0.0500	2.477506	0.558769	32	157.3884	0.1369
Treat.*Block	0.0500	2.477506	1.841303	32	38.11695	0.6215

Figure 18. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Fresh Weight of Leaves by Treatment

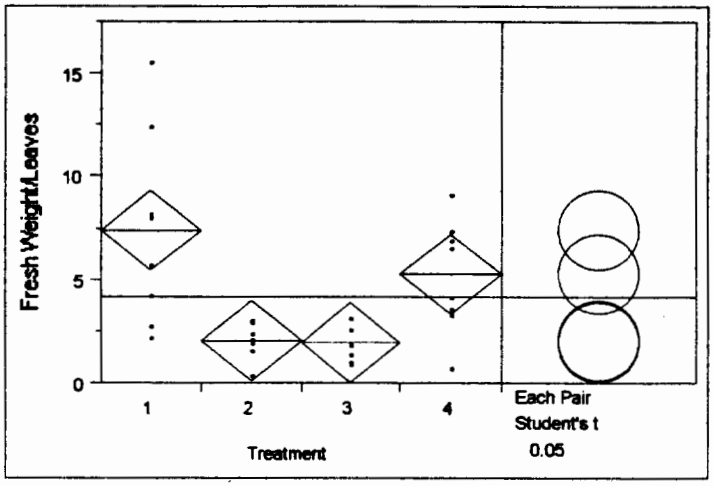


Table 93. Descriptive statistics for dry weight of leaves (Kg) per treatment and block 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	3.456	1.994	1.25-6.4	Block I	2.212	1.537	0.8-5.25
Treat.2	1.044	0.427	0.2-1.5	Block II	1.556	0.678	1.0-3.1
Treat.3	0.950	0.346	0.5-1.5	Block III	2.369	2.355	0.5-6.4
Treat.4	2.406	1.102	0.5-3.8	Block IV	1.719	1.231	0.2-3.8
Totals	1.964	0.967	0.2-6.4	Totals	1.964	1.450	0.2-6.4

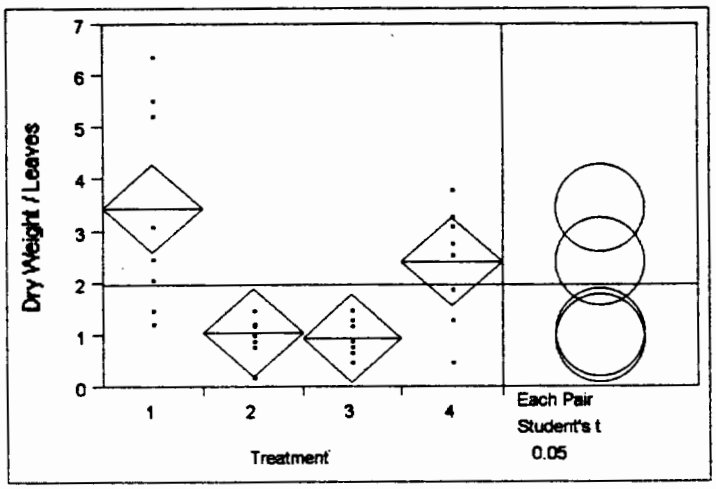
Table 94. Analysis of variance for dry weight of leaves 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	34.380	11.460	17.055	0.0001	0.4719
Blocks	3	3.616	1.205	1.794	0.1889	0.0496
Treat./Blocks	9	24.104	2.678	3.986	0.0079	0.3308
Error	16	10.751	0.672			0.1475
Total	31	72.851				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	0.819727	1.036515	32	18.83995	0.9999
Blocks	0.0500	0.819727	0.336148	32	51.24187	0.3784
Treat.*Block	0.0500	0.819727	0.867908	32	25.21688	0.9345

Figure 19. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Dry Weight of Leaves by Treatment



Fresh and Dry Weight of Rhizomes/Roots. To measure this, the rhizome and attached roots were separated from the aerial part of the seedlings. It was decided to weigh the rhizome together with roots, since this structure constitutes the main part of the underground bulk of the seedlings to which most of the roots are attached. Results for fresh and dry weight of rhizome/roots are shown in Tables 96 and 97. Treatments also accounted for significant differences in terms of fresh and dry weight of rhizomes/roots (Tables 96 and 98). This differences were reflected on a very significant p-value (0.0001) in the analysis of variance performed; blocks accounted for no significant differences (p=0.2056), and a significant interaction of effects was this time detected (p=0.0171). The situation here was very similar to that of leaves: the highest means were obtained in the weeded treatments (treatments 1 and 4), with that where shading was provided superior to that under direct sunlight. The superiority of treatment 1 (Shading + Weeding) over treatment 4 (no Shading + Weeding) is confirmed by comparing these two treatments separately. In both cases (fresh and dry weight), the differences between them was significant (although only barely significant in the case of fresh weight (p=0.0522; for dry weight= 0.02085). Comparison between weeded and non-weeded treatments revealed a highly significant difference between them (p-values < 0.0001, for both fresh and dry weight). There was no difference between the two lowest means recorded in the non-weeded treatments (p-values= 0.8992 and 0.8090, respectively for fresh and dry weight). In both cases, the beneficial effect of weeding on the weight of the biomass produced is clear. Figures 20 and 21 provide the visual comparison of the means for fresh and dry weight of rhizome/roots by treatments.

At this point, it is very difficult to say whether shading played a role in the superiority of treatments in terms of rhizome and root weight, since from a certain point of the experiment this effect became experimentally confounded with that produced by the shade resulting from the developing vegetation in the plots.

Table 95. Descriptive statistics for fresh weight of rhizomes+roots (Kg) per treatment and block 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	6.867	3.935	1.92-12	Block I	3.756	3.374	1.0-10.45
Treat.2	1.265	0.583	0.3-2.14	Block II	2.628	1.697	0.95-5.75
Treat.3	1.156	0.505	0.5-2.2	Block III	4.444	4.883	0.86-12.0
Treat.4	4.700	2.202	0.95-7.75	Block IV	3.161	2.705	0.3-7.75
Totals	3.497	1.806	0.3-7.75	Totals	3.497	3.164	0.3-7.75

Table 96. Analysis of variance for fresh weight of rhizomes/roots (Kg) 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	186.147	62.049	21.686	0.0001	0.5595
Blocks	3	14.658	4.886	1.708	0.2056	0.0440
Treat./Blocks	9	86.106	9.567	3.344	0.0171	0.2588
Error	16	45.780	2.861			0.1376
Total	31	332.691				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	1.691528	2.411867	32	18.47701	1.0000
Blocks	0.0500	1.691528	0.676813	32	53.50377	0.3616
Treat.*Block	0.0500	1.691528	1.640372	32	27.35522	0.8784

Figure 20. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Fresh Weight of Rhizome/Roots by Treatment

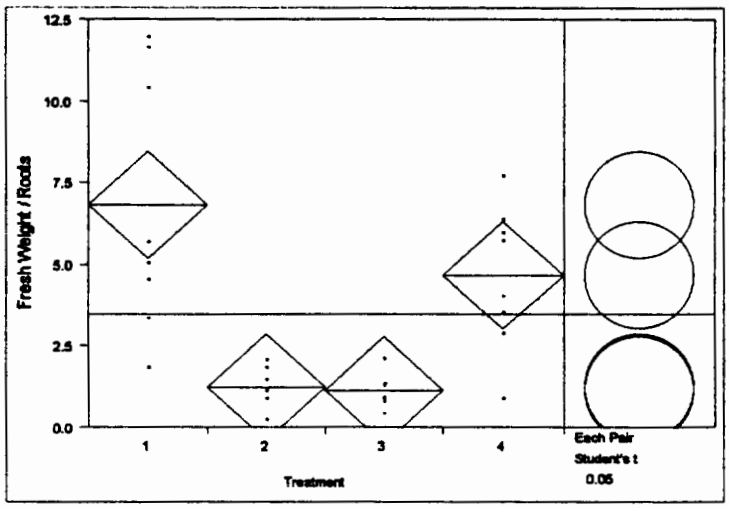


Table 97. Descriptive statistics for dry weight of rhizomes+roots (Kg) per treatment and block 5.4 years after planting of seeds.

Treatment	Mean	SD	Range	Blocks	Mean	SD	Range
Treat.1	2.869	1.632	0.9-5.2	Block I	1.694	1.553	0.4-4.8
Treat.2	0.600	0.249	0.2-1.0	Block II	1.119	0.616	0.4-2.2
Treat.3	0.506	0.212	0.25-0.9	Block III	1.825	1.942	0.25-5.2
Treat.4	2.069	1.012	0.5-3.6	Block IV	1.406	1.205	0.2-3.6
Totals	1.511	0.776	0.2-5.2	Totals	1.511	1.329	0.2-5.2

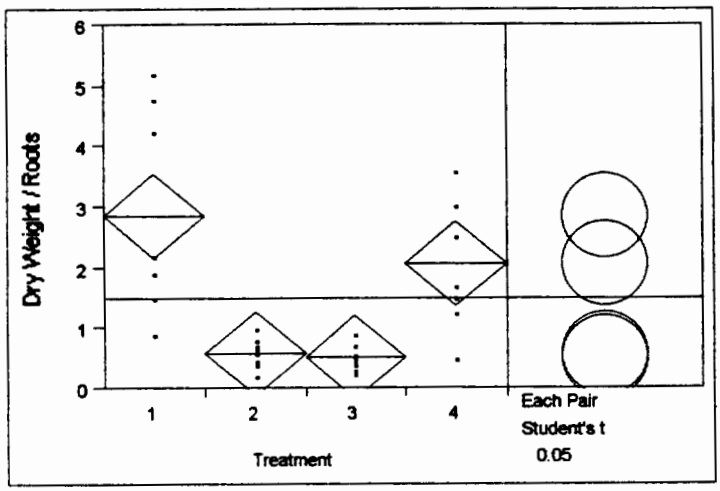
Table 98. Analysis of variance for dry weight of rhizomes/roots 5.4 years after planting of seeds.

Source	df	Sum of Squares	Mean Square	F-test	P-value	R-Square
Treatments	3	31.952	10.651	18.292	0.0001	0.5458
Blocks	3	2.375	0.792	1.359	0.2908	0.0405
Treat./Blocks	9	14.891	1.655	2.842	0.0329	0.2543
Error	16	9.316	0.582			0.1591
Total	31	58.534				

Source	Alpha	Sigma	Delta	Number	LSN	Power
Treatments	0.0500	0.763063	0.999251	32	18.72356	1.0000
Blocks	0.0500	0.763063	0.272409	32	65.70374	0.2929
Treat.*Block	0.0500	0.763063	0.682154	32	29.88138	0.8098

Figure 21. Visual Comparison of Group Means for Treatments with Graph of Student's t tests for Each Pair of Means

Dry Weight of Rhizome/Roots by Treatment



5.1.6 Conclusions

Despite of the generally satisfactory response of babassu seedlings to the stress conditions, some separate conclusions can be drawn for each of the parameters measured for the experiment.

1. Germination - Germination of whole fruits in field conditions is very nonuniform, but the seeds protected by the hard pericarp may keep their viability for over one year. I estimated 18 months as the maximum period of time for seed germination (whole fruits). This estimate is based on the length of the seedlings and growth rate measured at year 2.4. Treatments had a significant effects on germination, and this effect was clearly beneficial when shading and weeding were applied in combination, suggesting that whole fruits germinate better under direct sunlight. In experiments where kernels were excised from fruits there was no difference in germination rate under shading or direct sunlight. However, whole fruits have a thick pericarp that may require the effect of light in order to give the seeds inside the signal for germination. This would facilitate the use of whole fruits as seeds in degraded areas, since light usually gets to the soil surface given the nature of the existing vegetation.

2. Number of seedlings - If we consider the mean number of seedlings recorded in the first census (39.8) and in the last one (44.5), it tells us that in a period of time of 5.4 years this number remained very stable and no losses of seedlings occurred. This is very important

data for the purpose of this experiment, which confirms the resilience and aggressiveness of the babassu palm as a successional species, even in unfavorable conditions as those to which they were submitted. Obviously, this resilience cannot be measured only by the ability to remain alive, but this fact itself can be considered as a positive trait. The treatments had no effect on the number of seedlings throughout the experiment, although we could observe that most of the seedlings' "disappearance" happened during the dry season in non-shaded plots. However, the ratio of 1 seedling to 1 seed never dropped below that in any period while the experiment lasted. The significant effect of blocks on the number of seedlings detected in the analyses of variance for all censuses (except for the one year census), is difficult to explain. Block 1 and 2 always showed the best mean number of seedlings and they were two blocks in the same position, one in front of the other. The position of the blocks in relation to the incidence of light on the plants could have some effect on this result; or, a slightly different soil condition; or any factor that could cause the difference from between these two and the others. However, since the number of seedlings remained unchanged throughout the experiment, this cannot be considered a matter for further investigation. An important point was the "reappearance" of 9 seedlings in the last census, confirming the ability of this palm to keep the underground apical meristem alive for long periods of time, until more favorable conditions are achieved for the production and launching of new leaves.

3. Leafing - Treatments had no effect on seedling leaf production. A significant result for treatment effect was recorded only in the initial analysis (one year), but it can be interpreted mostly as a consequence of the germination results in that first year. From that point on, no significant effect of treatments could be detected in any census. The number of leaves, however, experienced increases and decreases related to the dry and rainy seasons. A decrease in the number of leaves borne by the seedlings usually happened during the dry seasons; in general, during this season, the plots where shading was provided had seedlings with a smaller decrease in the number of leaves. In plots under direct sunlight, the seedlings tended to shed more leaves (in order to reduce photosynthetic area), and ultimately, the overall physiological activity. During the rainy season, on the other hand, the tendency of seedlings seemed to be to increase the number of leaves, and to retake full physiological activity in order to compete for very scarce soil nutrients, rather than moisture. In this season, day length is shorter and the seedlings in non-weeded plots had surrounding vegetation as an obstacle for light absorption, -- this was probably the reason why those plots had higher increases in number of leaves. This stable leafing pattern observed throughout the experiment matches the pattern observed in nature .This may suggest a genetically established continuous leafing rhythm which is not easily altered by external factors.

4. Growth - This was affected by treatments up to 3.3 years after the seeds were planted; after that, no significant effect could be detected by the analyses of variance performed. This shows separate effects on different physiological processes: growth rate seems more likely to be affected by external effects than leafing rate. This may be because, from physiological and ecological standpoints, the development of a strong root system and the maintenance of a balanced number of leaves according to the season and availability of resources (e.g. water, nutrients), can more advantageous than spending physiological effort on growth in height, at least in the earlier phases of growth. From a certain developmental stage on, when the establishment phase is overcome, growth is fully retaken and babassu seedlings are ready to take over of the landscape. During the first three years , when treatments produced differences in growth, an alternating situation could be observed that was directly related to the season of the year. In the dry season, the best growth performances were achieved by the seedlings in non-weeded plots; not because the competition stimulated that, but because higher levels of moisture were maintained in those plots. In the rainy season, the situation was the opposite: weeded plots did better than the non-weeded plots, although the best results were obtained when the combination shading and weeding was provided. This suggests that the seedlings would grow better in more shaded conditions, in their early stages of growth. This situation was also true after 3.3 years, when treatment effects could not be detected any more, but higher means were still recorded for treatments that combined shading and weeding.

5. Fresh and Dry Weight of Leaves and Roots - These were the characters measured for which the anovas performed revealed the highest p-values for the treatments applied. This highly significant effect of treatments on both fresh and dry weight of leaves and roots shows that the features most affected were weight of the biomass produced, both aerial and underground. It appears that while unfavorable overall conditions (that including treatments, poor soil, and periodic water shortage in a soil type that does not hold much moisture for long periods of time even in the rainy season), had no apparent effect on survival of seedlings, leafing and growth, but they did produce strong differences in terms of biomass accumulation in the whole plant. It is very clear that the treatments that account for most of this highly significant overall effects were the weeded treatments (1 and 4), which were clearly superior to the others in terms of leaf and rhizome/root weight. It shows that babassu seedlings, while withstanding well competition with the surrounding vegetation in the non-weeded plots, do much better in the absence of the competitive vegetation.

The overall conclusion of this experiment is that babassu seedlings can successfully establish themselves in degraded sites. Although for separate characters measured at different developmental stages and after periods of shortage or availability of water, the responses are varied, the overall response to treatments and stress conditions for which the seedlings were subjected leads to the conclusion that babassu will succeed in establishing itself in degraded soils. Whether this palm will keep a reasonable level of productivity can be only be determined in a much longer term study. However, if we

consider that these are areas where currently only grass and weeds can grow, the introduction of a valuable plant species which is likely to succeed, may be worth trying; this may be the beginning of the recuperation process of the plant coverage of the soil with a palm of recognized social and economic value. Moreover, the use of other Orbignya species which grows in areas often subject to water deficit and poor soil conditions can be an additional alternative. An example of such "babassu" species is Orbignya teixeirana, an interspecific hybrid between the "true babassu" Orbignya phalerata Martius and the *piaçava* palm Orbignya eichleri Burret. The establishment of babassu stands in those degraded areas would be starting point for implementing many other alternative land uses, that are currently very restricted, including agro-forestry systems that are likely to be successful in association with the babassu palm.

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List of Photographs in Apendix I

Experiment - Development of a Rapid Technique for Field Determination of Kernel/Fruit Ratio: 1 - 2

1. Drying fruits in the field with portable oven.
2. The small size and light weight of the portable oven permit easy use in the field.

Experiment - Nutrient Requirements of the Babassu Seedling: 3 -16

3. Small greenhouse for seed germination and early growth of seedlings.
4. View of boxes with vermiculite for seed germination.
5. Transplanting of seedling from the germinator to plastic bag.
6. Close-sided shed built with babassu leaves for seedling protection.
7. View of plastic bags and seedlings by the time of transplanting.
8. Seedlings in the nursery under ca. 70 % sun light.
9. View of nursery with increased spacing between plants, 15 months after transplanting.
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11. Seedling removed from the plastic bag for the final data collection - August, 1994.
12. View of the working area where seedling parts were separated, measured and weighed.
13. Measurement of leaf and counting of pinnae.

List of photographs (cont'd)

14. Weighing of leaves of seedlings.

15. View of rhizome/roots of seedling.

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Experiment - Establishment of Babassu in Degraded Soils: 17 - 31

17. View of plot without weeding.

18. Plot with shading and weeding.

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22. General view of block showing plots under the different treatments.

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24. The search for seedlings in a non-weeded plot.

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25. Shading had a significant effect on seedling development during the dry season for maintaining some moisture content in the soil.

26. View of three treatment plots: no shading + no weeding (left), no shading + weeding (center), and shading + weeding (right).

List of photographs (cont'd)

27. View of seedling and type of soil in a weeded plot.

28. Seedling dug out of soil for final data collection - August, 1994.

29. Measurement of seedling parts - August, 1994.

30. Weighing of seedling parts - August, 1994.

Apendix I

Photographs

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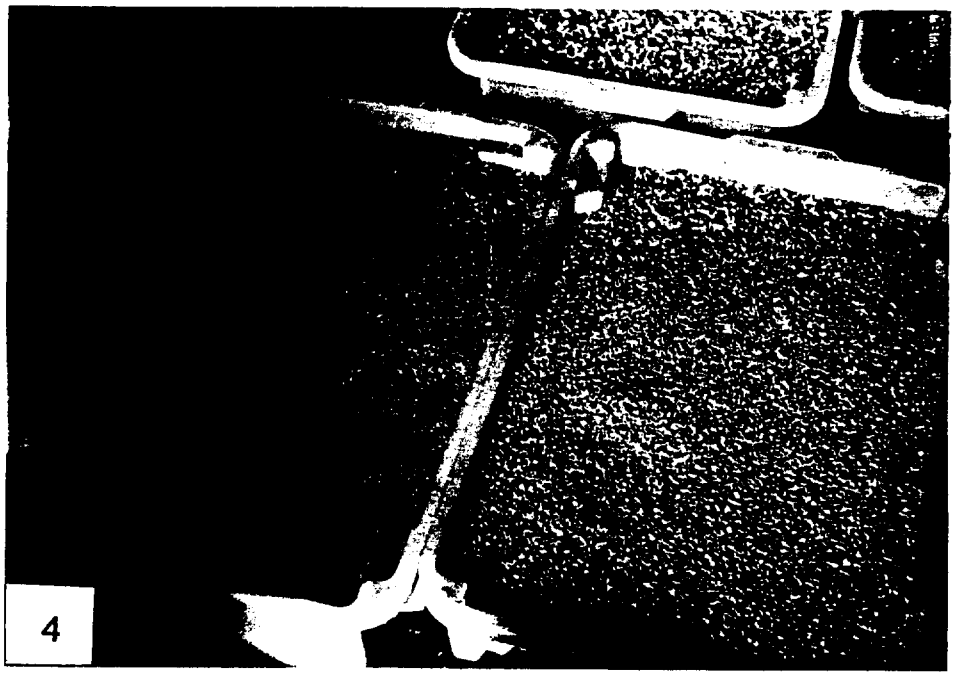

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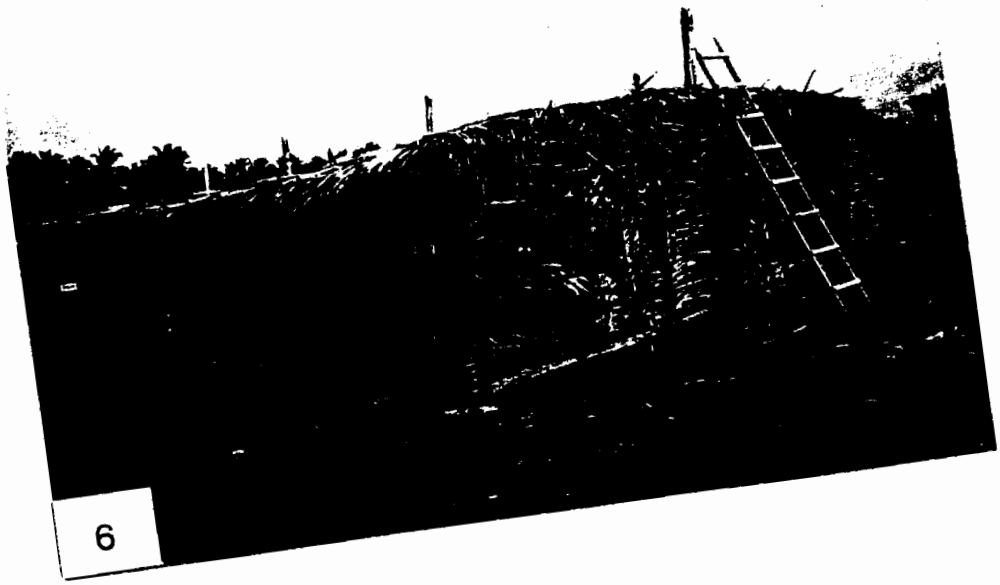

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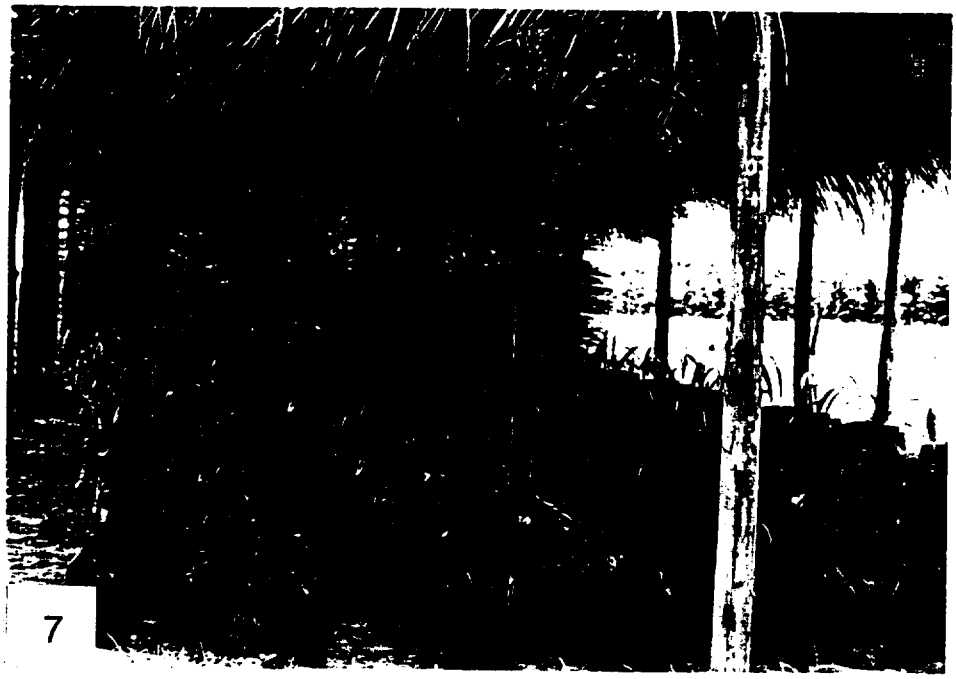

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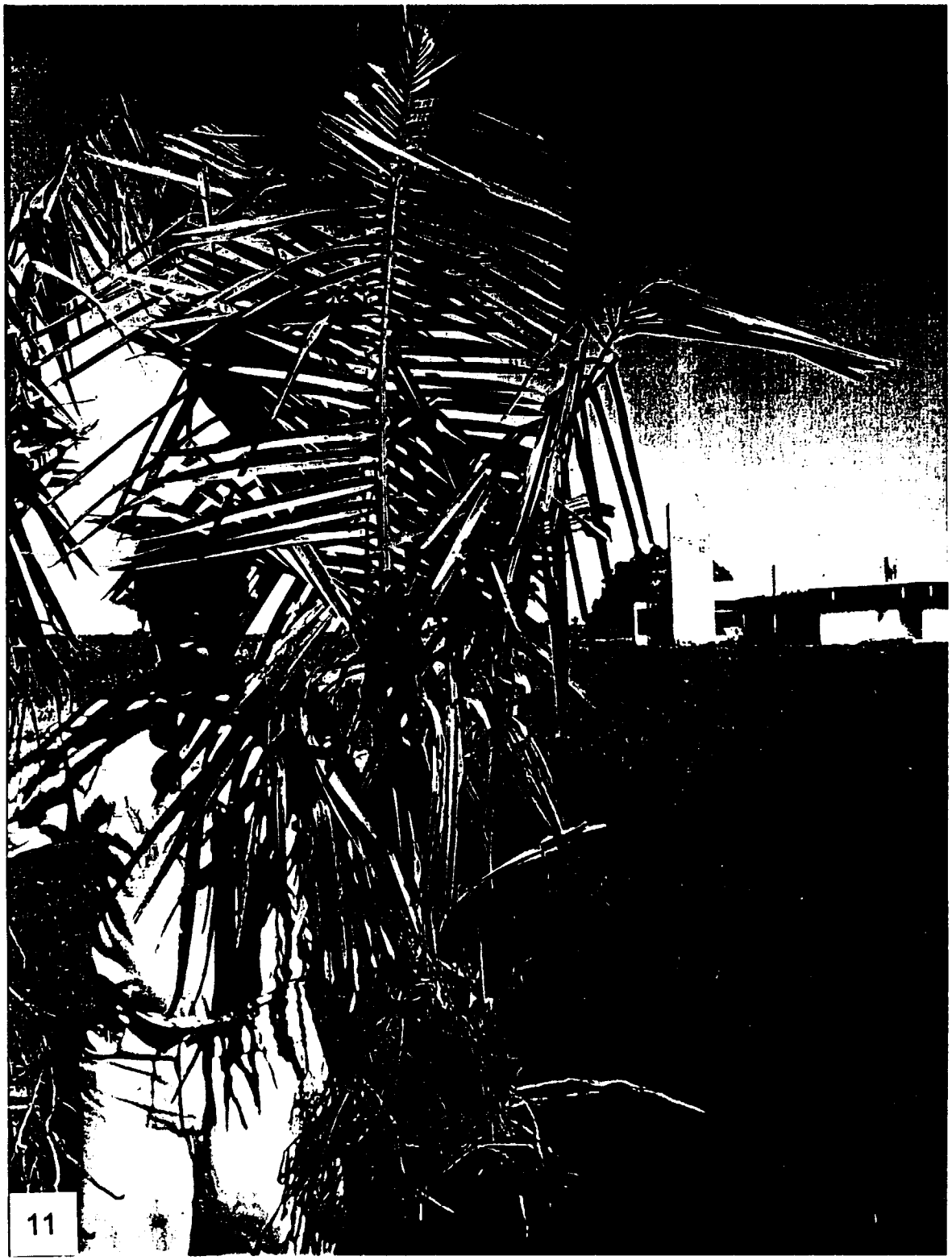

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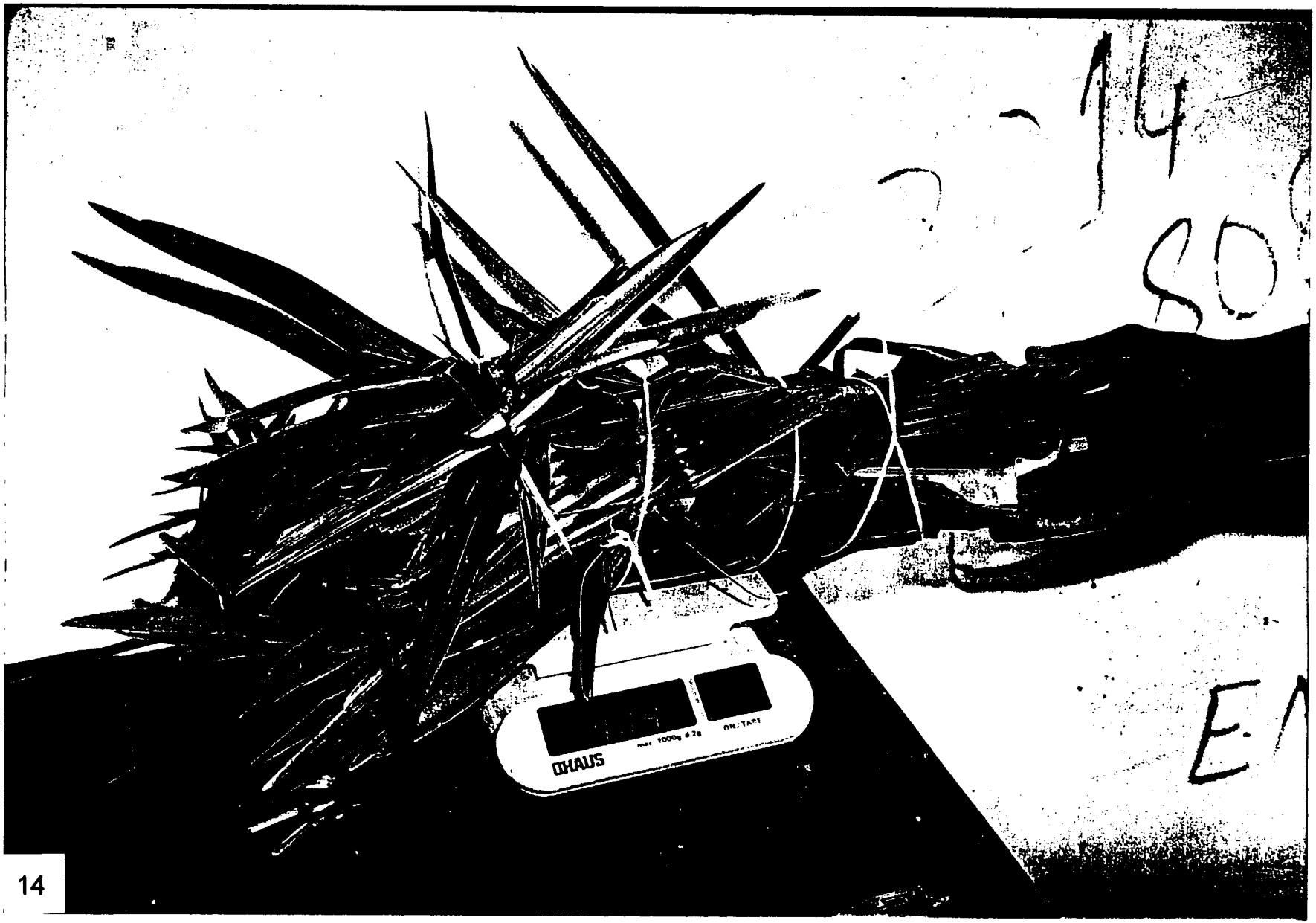

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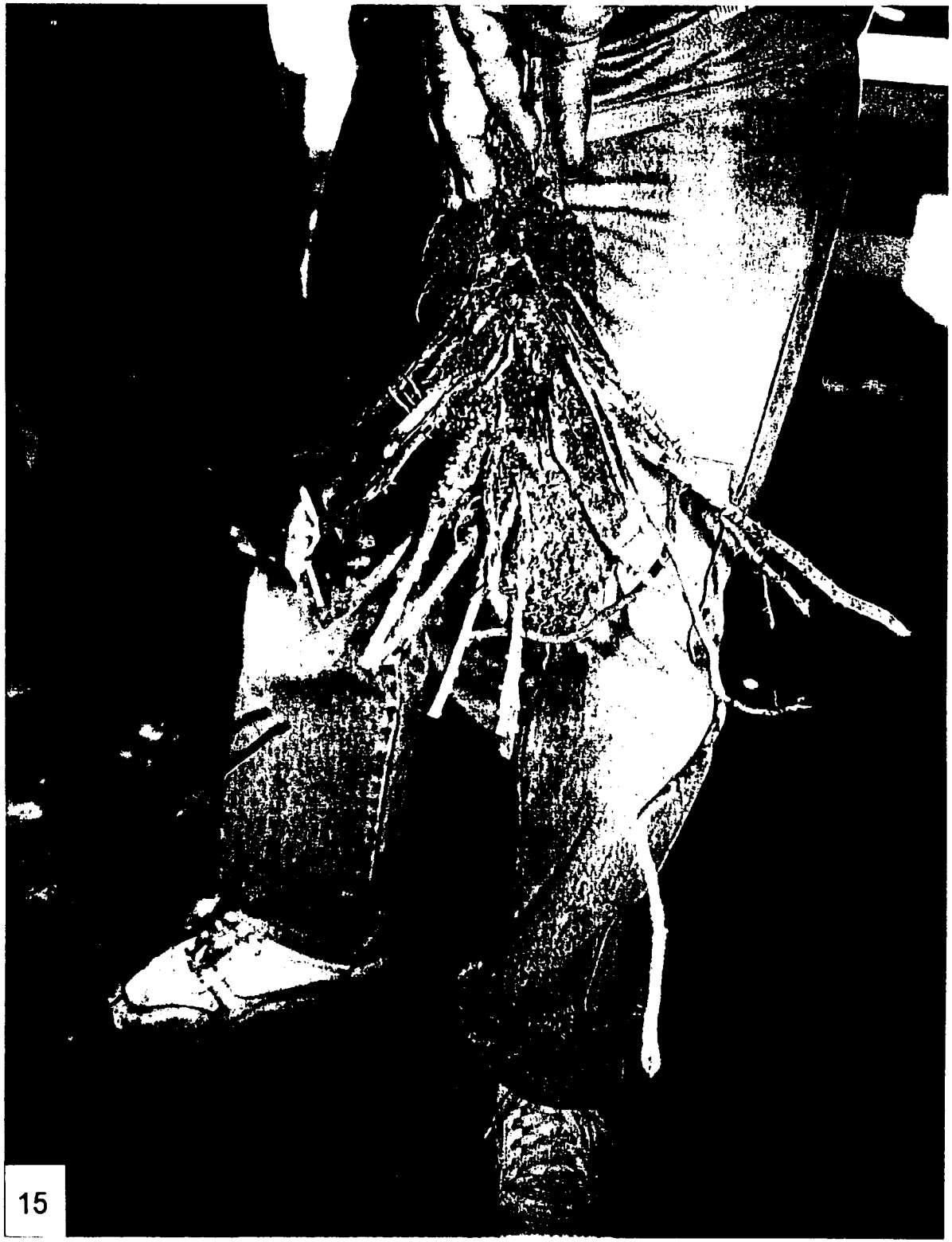

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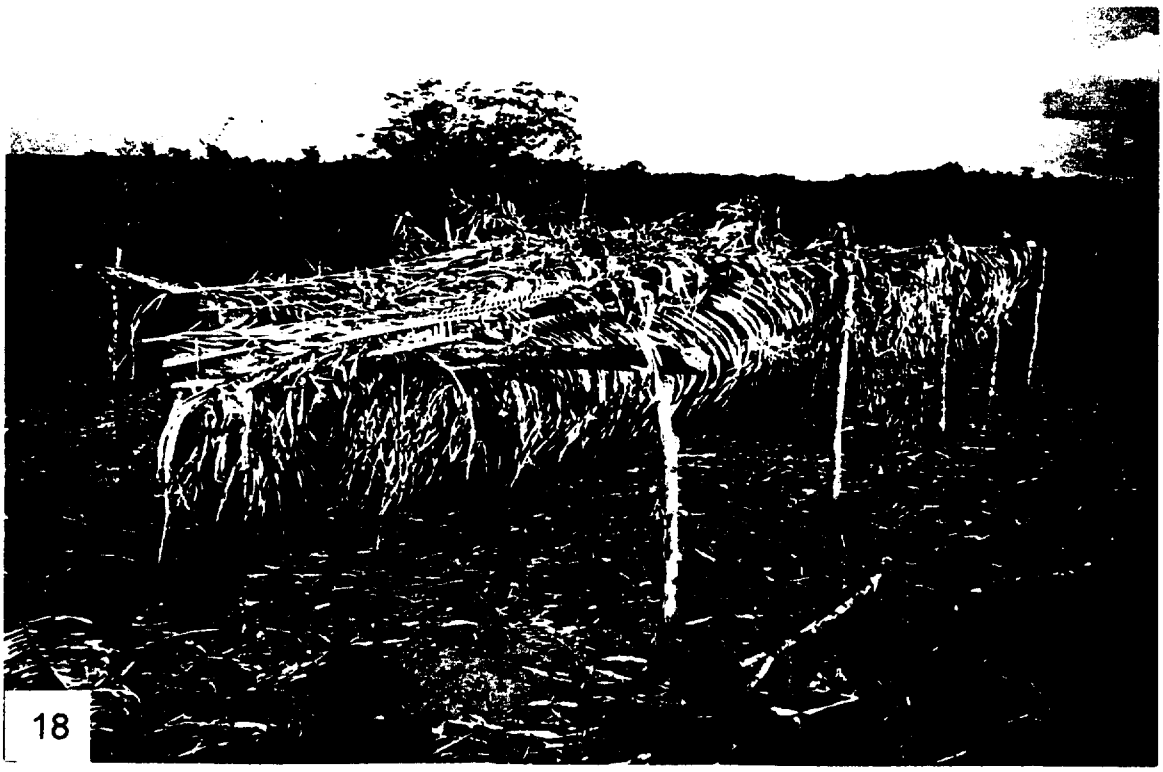

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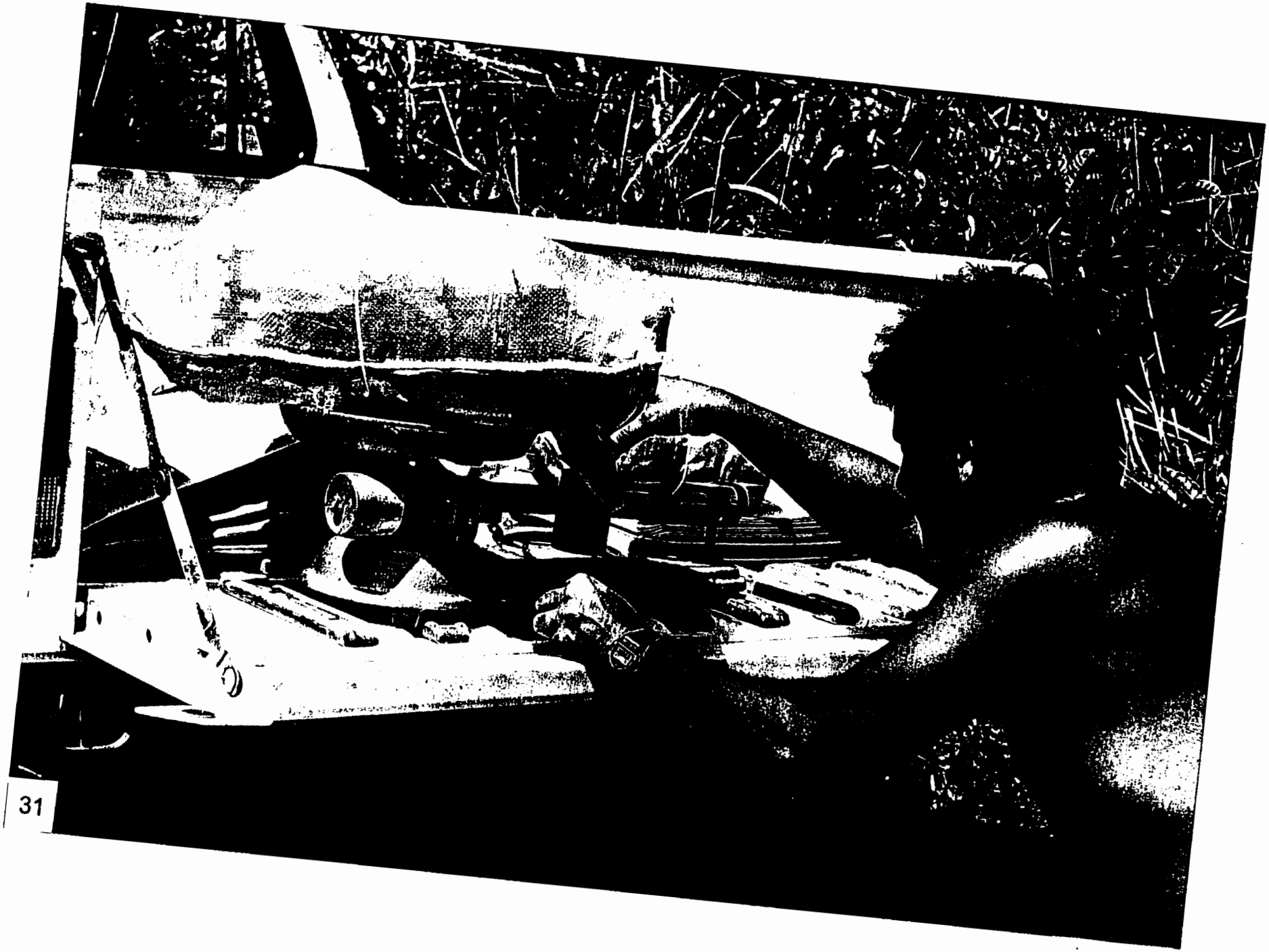

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