ATLANTIC ZONE PROGRAMME

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PALMITO (*Bactris gasipaes H.B.K.*) CULTIVATION IN THE ATLANTIC AND NORTHERN ZONE OF COSTA RICA

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The Atlantic Zone Programme (CATIE-AUW-MAG) is the result of an agreement for technical cooperation between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), the Agricultural University Wageningen (AUW). The Netherlands and the Ministerio de Agricultura y Ganadería (MAG) of Costa Rica. The Programme, that was started in April 1986, has a long-term objective multidisciplinary research aimed at rational use of the natural resources in the Atlantic Zone of Costa Rica with emphasis on the small landowner.

PREFACE

General description of the research programme on sustainable Landuse.

The research programme is based on the document "elaboration of the VF research programme in Costa Rica" prepared by the Working Group Costa Rica (WCR) in 1990. The document can be summarized as follows:
To develop a methodology to analyze ecologicaly sustainable and economically feasible land use, three hierarchical levels of analysis can be distinguished.
1. The Land Use System (LUS) analyses the relations between soil type and crops as well as technology and yield.
2. The Farm System (FS) analyses the decisions made at the farm household regarding the generation of income and on farm activities.
3. The Regional System (RS) analyses the agroecological and socio-economic boundary conditions and the incentives presented by development oriented activities.

Ecological aspects of the analysis comprise comparison of the effects of different crops and production techniques on the soil as ecological resource. For this comparision the chemical and physical qualities of the soil are examined as well as the polution by agrochemicals. Evaluation of the groundwater condition is included in the ecological approach. Criterions for sustainability have a relative character. The question of what is in time a more sustainable land use will be answered on the three different levels for three major soil groups and nine important land use types.

Combinations of crops and soils

	Maiz	Yuca	Platano	Piña	Palmito	Pasto	Forestal I II III
Soil I	x	x	x		x	x	x
Soil II						x	x
Soil III	x			x	x	x	x

As landuse is realized in the socio-economic context of the farm or region, feasibility criterions at corresponding levels are to be taken in consideration. MGP models on farm scale and regional scale are developed to evaluate the different ecological criterions in economical terms or visa-versa.

Different scenarios will be tested in close cooperation with the counter parts.

ACKNOWLEDGEMENTS

When I was working in Costa Rica, I received help from many people. With help from them I could write this report. I am very grateful for them.
First I want to thank ir D. Jansen who was my supervisor in CR. With advices from him I could manage the measurements of the fertilizer trial. Furtheron I want to thank him for his and his wifes' hospitality. Who knows, until the next tennis match and a nice big pizza (this time it's on mine)...
Thanks too for the help of the Costa Rican staff. Especially Enrique ("*Gordo*") and Don Mario who helped me with chopping plants for obtaining data on dry matter weight. I sent my greetings to Don Marios' family. "*Buena suerte!*"
And of course Celia who always was in for a nice talk and who made sure that there always was coffee.
I am very grateful to ing. Ernesto Requeno Molina. He made it possible for me to stay on the project "*CARE Internacional en Costa Rica*". From him and the extensionists I learned really a lot about palmito cultivation by smallholders. And the time I had in Upala itself I would describe as unforgettable. Sentences as "*pura vida*", the beer "*Imperial (para gente grande)*" and the dancing "*Maracabu*" I will always remember.
Last but not least I want to thank all the students of "Programma Zona Atlantica" who also made my stay at CR very pleasant.

SUMMARY

This report consists of three parts: 1) a literature study (description of the Atlantic Zone of Costa Rica, of "Programma Zona Atlantica", of peach palm plants and its cultivation and of the nutrient cycle of the palmito cropping system), 2) a N-P-K fertilizer trial for palmito (*Bactris gasipaes H.B.K.*) and 3) a description of a practical period fulfilled at the development organization "*CARE Internacional en Costa Rica*" in Upala (Northern CR).

Peach palm ("*palmito*") is a plant that is cultivated for its inner stem part and its fruits. A peach palm plant consists of various suckers. In the Atlantic Zone of CR peach palm cultivation is very important. Fertilization has big effects on the amount of production of inner stem parts.

In the N-P-K fertilizer trial significant fertilizer effects on peach palm plants and its suckers are recorded. Positive significant N-effects are recorded for total number of suckers per plant, actually present (cut leaves excluded) and total (cut leaves included) leaf area per sucker, leaf areas for last and second- last leaves, height of the sucker of where last leaves disperse, the number of harvested suckers, increases per day of the height of where last leaf sheaths disperse and the increases per day of the number of total formed leaves per sucker. A positive significant PK-effect only can be found on the total number of suckers per plant.

The practical period at the development project "*CARE Internacional en Costa Rica*" leaded to a better understanding of palmito cultivation by smallholders. Especially infrastructure (communal organizations (committees for credit, for guarding communal money, etc)) seems to be very important to them. Furtheron the set-up of the CARE-project and the way the staff cooperated with the farmers (advices to the farmers and feed-back to the projects staff) seems very important if the whole is to be made a success.

SAMENVATTING

Dit rapport bestaat uit drie delen: 1) een literatuurstudie (beschrijving van de Atlantische Zone van Costa Rica, van het "Programma Zona Atlantica", van palmito planten en hun cultivatie en van de nutriënten cyclus van het palmitocultivatie systeem), 2) een N-P-K bemestingsproef voor palmito (*Bactris gasipaes H.B.K.*) en 3) een beschrijving van een stage in het ontwikkelingsproject "*CARE Internacional en Costa Rica*" in Upala (Noord CR).
Palmito is een plant die wordt verbouwd voor het binnenste gedeelte van z'n stam en voor zijn vruchten. Een palmitoplant bestaat uit verschillende scheuten. In de Atlantische Zone van CR is palmitoverbouw erg belangrijk. Bemesting heeft groot effect op de productie van de stamprodukten.
In de N-P-K bemestingsproef zijn significante bemestingseffecten gevonden op de palmitoplanten en de individuele scheuten. Significante positieve N-effecten zijn gevonden op het totale aantal scheuten per plant, het aanwezige bladoppervlak (exclusief gekapte bladeren) en het totale bladoppervlak (inclusief gekapte bladeren) per scheut, bladoppervlakten van laatste en op één na laatste gevormde bladeren, hoogte van de scheut waar laatste bladscheden uit elkaar gaan, het aantal geoogste scheuten, dagelijkse toename van de hoogte van de scheut waar laatste bladscheden uit elkaar gaan en de dagelijkse toename van het totale aantal gevormde bladeren per scheut. Een positief significant PK-effect kan alleen gevonden worden op het totale aantal scheuten per plant.
De stage aan het ontwikkelingsproject "*CARE Internacional en Costa Rica*" leidde tot een beter begrip van de palmitocultivatie door kleinschalige boeren. Infrastructuur (organisatie van boeren (commissie voor krediet, geldbewaring, etc.)) in het speciaal, blijkt zeer belangrijk te zijn voor hen. Verder is de opzet van het CARE-project en de manier waarop de staf met de boeren samenwerkt (advies aan de boeren en "feed-back" naar de staf) zeer belangrijk, wil het geheel een succes worden.

CONTENTS

List of Figures

1 INTRODUCTION

In the Atlantic Zone of Costa Rica, palmheart (Bactris gasipaes H.B.K.) is an important economical product. This product (the growing point of a palm in a juvenile stage), locally known as palmito, can perform very good in these humid tropical climate conditions. Although palmheart is grown for more than 20 years, it still has a quick expanding reputation and export market. Although recently prices are falling for palmhearts (partially due to the growing competition from Brazil) it is sometimes referred to as a crop of the future. To withstand the growing competition from Brazil, more knowledge is necessary. In the Atlantic Zone of Costa Rica little is known about crop responses to fertilizers. Research about this subject is therefore very useful.

Part I of this report consists of chapters 2 till 5. A literature study is presented too show some information about growth conditions in the Atlantic Zone of Costa Rica, about the Atlantic Zone programme, about the peach palm and about the nutrient cycle in a field that is cultivated with peach palm.

Chapter 6 forms part II and is about experimental work, practiced in the Atlantic Zone of Costa Rica. In this part, fertilizer effects on peach palms, grown for palmito, are analysed. The objective is to find out how the plants react to different levels of nitrogen, phosphate and potassium. Information on growth and development of the crop will be used for a crop growth simulation model. Ir. D. Jansen is working on this.
Analysed are effects on leaf area, leaf developing rate, number of living and dead leaves per sucker, number of suckers per mother plant, height of where last leaf sheaths disperse, number of harvested suckers, growth rate, specific leaf area, fresh and dry matter production of leaves.

The third part of this report is about quite different work. A short practical period (one month) was done at the development project "CARE Internacional de Costa Rica". Attention was paid to peach palm cultivation in its young development stage, and the way in which the project works.

The work presented in this report was done as a fulfillment of a practical period, obliged to obtain the Ir (MSc) degree at the Agricultural University Wageningen in the Netherlands. This practical period was done as part of the study Tropical Land Use (orientation Tropical Crop Science).

PART I:

2 THE ATLANTIC ZONE OF COSTA RICA

The Atlantic Zone of Costa Rica is situated in the east of the country, enclosed at the west side by the Central and Talamancan mountain ranges and at the east by the Caribbean sea. In the north the zone ends at the border with Nicaragua, whereas in the south it stops at the border with Panama (Figure 2.1).

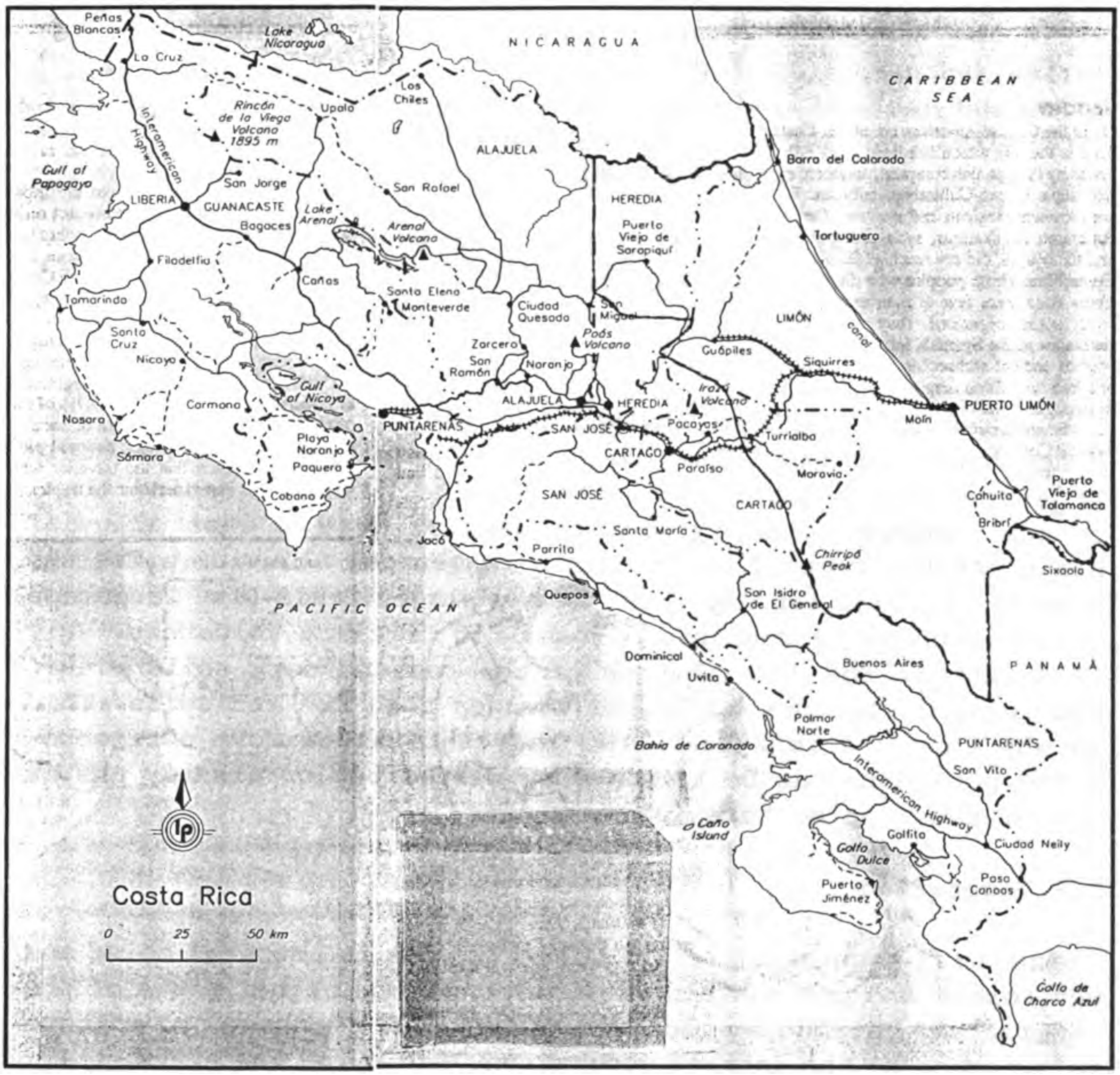

Figure 2.1 Location of the Atlantic Zone in Costa Rica.

Because there already exists so many literature (published by the Atlantic Zone Programme) about climate, soils, vegetation and land use, these subjects only will be presented here briefly.

2.1 Climate

According to Nuhn's classification (1978), the zone is part of the "tropical humid rain forest." Annual variation of temperature is dominated by the monsoon with the highest temperatures before the onset of the summer rains (Portig, 1976). Rain figures vary from 2500 mm * y^{-1} in the south-east to 4500 mm * y^{-1} in the north-east and east of the zone. Mean annual temperatures vary from 18 to more than 24 degrees Celsius, depending mainly on altitude. Potential evapotranspiration in the Atlantic Zone varies between 3 mm * d^{-1} in June and July to 4.2 mm * d^{-1} in March and April (Rojas 1985). This means that in much of the zone crop growth is possible throughout the year. Unfortunely this also is the case for weeds, pests and diseases.

For more detailed information Rojas (1985) listed 10 meteorological stations in the Atlantic Zone.

2.2 Soils

The Atlantic Caribbean lowland has been a sedimentation area since early Tertiary. The coast line is made up by a narrow strip of succeeding beach ridges with parallel canals. Behind this, coastal swamps occur, gradually passing into a vast alluvial plain. At the foot of the mountain ranges the alluvium takes the form of alluvial fan deposits. At few places, this flat landscape is interrupted by remnants of basaltic tertiary volcanoes. Very important is the distribution of the red and dark soils within the region. The dark soils are younger than the red soils. This is why they are less weathered and contain far more nutrients. These nutrients can be released by weathering or already are in a form that can be taken up by plants.

2.3 Vegetation

The natural vegetation of the Atlantic Zone is tropical moist and wet forest and pre-montane wet forest. On the higher parts of the central and Talamancan mountain ranges lower montane and montane rain forest is the natural vegetation. Following van Sluys et al. (1987) regional and local differences in appearence and species composition are mainly the result of (1) altitude, and in relation with this, mean temperature and temperature extremes, air humidity, precipation and soils, (2) the total annual rainfall as an ecological gradient from northwest to southeast, and (3) local relief and hydrology which are reflected in

drainage pattern and possible (periodic) flooding.
At present much of the forest has been destroyed as a result of wood extraction (Veldkamp et al., 1992) and of conversion into pasture and crop land.

2.4 Land use

The land use in the Atlantic Zone is very variable with regards to crops, management and field size. In the plain lowlands enormous banana plantations are found as well as small maize and cassava producing farms. In the north especially, large areas are used for pasture. Van Sluys (1987) stated that in the Atlantic Zone, perennial crops (among others banana, platain, coconut, coffee, cassava, sugar cane and peach palm) are emphasized in comparison with annual crops (among others maize, rice and beans).

3 PROGRAMMA ZONA ATLANTICA

In 1986 an agreement was made between the Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), the Wageningen Agricultural University (WAU) and the Ministerio de Agricultura y Ganadería (MAG). The Atlantic Zone Programme is the result of this agreement.
In 1991 the WAU linked finance of projects like this to results of investigations. The continuation of the project was secured by provisional finance for two years by the research programme *'A methodology for analysis and planning of sustainable land use, a case study in Costa Rica'*. In 1993 an evaluation of this research took place. A proposal for a parallelprogramme (which aims to transfer information to MAG and others) will be presented to prolong the project activities.
The Programmes' central theme is sustainable land use. It aims to develop a model to generate sustainable alternatives for the present land uses, executed on different system levels. These are:

- the land use system
- the farm system
- the regional system

The here presented research is thereby concentrated on the farm system (subsystem cropping system).

4 PEACH PALM

4.1 Taxonomy

The peach palm is a member of the Palmae family, Arecoidea, Cocoeae, in the genus *Bactris* with the specific name *gasipaes*. Also the genus name *Guilelma* sometimes is used. The author used in many publications is "H.B.K.", but sometimes "Khunt" is also used. It is worth mentioning that the International Board for Plant Genetic Resources (IBPGR) also uses the *Bactris gasipaes H.B.K.*-name.
In Central America the name pejibaye is commonly used. Other names are peach palm (English), pejivalle, pejiballe, picbae and pixbay (Costa Rica), chomtaduro, chontaduro (Ecuador), pupunha, pirijao (Brasil), macanilla (Venezuela), chonta and pejijuayo (Peru and Colombia).

4.2 Morphology

The morphology of the peach palm is determined by the way of cultivating it. When cultivated for the pejibaye (fruits), the plants can become quite high: when adult, up to about 12 to 20 metres. The more or less cilindric stem then has reached a diameter at the base between 20 and 30 centimetres. At the top a crown of about 20 adult, pinnate leaves is formed (see figure 6.1 b). These pinnate leaves can grow up to a length of between 1,5 and 4 metres and to a width between 0.6 and 1.6 metres.
In contrary to this, when cultivated for palmito the plants are harvested in quite a young stage (for the first time after 12-18 months), before reaching the stage of sexual reproduction. The stem then usually has a diameter of about 9 cm. In this stage the plants still posess some bifid leaves (see figure 6.1 a), although the newest leaves are all pinnate types, although in most cases not yet as big as the pinnate leaves of the older plants which are cultivated for their fruits.
Especially when peach palms grow older it is clearly visible that the individual internodes on the stem are covered with densely packed spines (perpendicular to the stem). Among plants with the same age, the ones with the longest internodes are also the highest ones (CENPRO, 1985).
It is not only the stem that is covered with spines, but also the leaf raches (although in a lesser amount). Nowadays experiments with spineless peach palm trees are done but it is believed that these plants produce less suckers and thus have a lower palmito yield.

The major part of the roots of the peach palm grow laterally (borne near the base of the stem) and superficial and form a dense network in the top 20 centimetres of the soil. Here about 60 % of the total root mass is located (CYRUS CYRUS, 1983).
The peach palm posesses a rhizome which consists of suckers ("*hijos*") and the central stem. Together they form the "*cepa*".
The inflorescences appear in about 4 or 5 years after germination. Potentially the plant can produce one inflorescence and thus one bunch of fruits per every leaf it produces. But normally this is not the case because it can only produce a number of inflorescences in accordance with its nutritional status (MORA URPI, 1984). The inflorescence is protected by a fly-leaf, covered by spines. The inflorescence consists of one central axis which in turn consists of about 60 single little branches. Each little branch consists of about 20,000 masculine and about 300 feminine flowers. The female flowers have to be pollinated by other plants because otherwise only small fruitbunches will be produced caused by falling of unpollinated fruits or by presence of only fruits without seeds (MORA URPI, 1984).

4.3 Growing conditions

The peach palm grows especially good in the Atlantic Zone of Costa Rica. This probably because the rainfall is sufficient in this region. It is believed that peach palm performs at best in those regions that are characterized as having a natural vegetation as "humid tropical forest" (VILLAPLANA, 1982). This is also the natural habitat for the peach palm. The peach palm grows at best when there is ample rainfall throughout the year (1,900 mm up to more than 6,000 mm) (MORA URPI, 1984). But bad drainage conditions should be prevented because the plant can't deal with excessive water. When dry periods are part of the year, decreases in yields during these periods can be high.
The peach palms growth is influenced also by weed competition. Especially by gramineae, because the root type of the peach palm is lateral and superficial.
Although the peach palm can be found up to about 2,000 metres above sea level, commercial cultivation only is possible between sea level and 800 metres higher. When grown at higher levels the growth speed would drop to a too low value.
The mean temperature in which palmito is grown is between 24 and 28 °C. Higher temperatures don't limit the production much, especially when there is sufficient water (ALMEYDA et al., 1980).

4.4 Management

A distinction is made between management of large plantations and plots managed by small farmers. Most literature for the descriptions below stems from "The pejibaye palm (Bactris gasipaes H.B.K.)"(MORA URPI et al., 1984).

Field selection.
Fields preferably should conform to the criteria for the growing conditions mentioned in the preceding paragraph. When possible fields should be selected with good drainage conditions, on reasonable fertile soils (preferably), on flat areas and below an altitude of 800 m above sea level. Palmito still grows reasonable good on acid soils which have a pH of about 4.5. Mostly these soils are poor in nutrients but fertilizers can compensate for this.

Indeed all the big plantations have located their fields on flat areas, but small farmers sometimes use areas on slopes. Large differences exist in land area under palmito. Small farmers cultivate a mean area of 1.82 ha in the canton Sarapiquí of the province Heredia and 2.50 ha in the canton Pococi in the province Limon (see figure 2.1). Big plantations can cultivate even more than 700 ha (for instance *Agropalmito S.A.*, a big plantation in Guápiles (Pococí)).

Preparation of the fields.
The way fields should be prepared depends for a great part on the way the field was used before this preparation.
When the field already is quite clean, only weeding will suffice. When the field is a bit "hilly" some leveling of the field and burning of possible present trees should be performed. And when the field was used as grassland, mechanised preparation (cultivating) is recommended. When there are a lot of weeds, chemical treatment has to be practised.

Because most small farmers don't have the opportunity to use mechanical equipment, they often use chemical sprays to get rid of weeds. Felled trees normally stay in the fields.

Nursery.
Selected seeds are germinated in plastic bags or on germination tables. But before putting the seeds into plastic bags, they often are treated with fungicides, and are brought in the right humidity condition. In this way germination starts after 1.5 -2

months.
On the tables, seeds are sown at 2-3 cm between seeds and 7-8 cm between rows. Germination starts after 2-4 months. For this germination type it is good to give a so called "complete fertilizer" (e.g. 12-24-12; 12% N, 24% P_2O_5, 12% K_2O and spore-elements) 1-2 months after germination. Weed competition should be prevented, so weeding is necessary.
A couple of weeks after germination the seedlings can be placed in a special bed with a width of ca. 1.20 m and with an elevated level at ca. 20-25 cm high. Here also the seedlings that germinated at the tables can be placed (normally ca. 3 months after germination).
The plant distance can be around 40 cm between plants. The plants need shade until they reach the 3-4 leaves stage with a height of 20-30 cm. Fertilization is recommended (nitrogen and phosphate). After some time they can be placed in the field.
An alternative is that the seedlings are put into black plastic plantbags (usually 20*30 cm). These bags can be placed against each other in rows. Also shade is needed. Again fertilization is recommended.

Because germination in plastic bags is far more elaborated, this method usually only is practised by big plantations. Small farmers normally practise the other way of germination.
On big plantations the special beds and black plant bags are fertilized, but among small farmers this not always is done.

Transplanting.
Because root damage is hard to overcome for the young plants, they need to be handled very carefully. Plants need to be planted in holes of 20*20*20 cm, preferably on cloudy days, when the ground is wet. Fertilizer can be given at transplanting or later.
To prevent too serious transpiration, last (youngest) leaves can be cut or/and an anti-transpirant (for instance a 2.5% sugar solution) can be applied.
It also is recommendable to use a mixture of herbicides that contains a direct action and a pre-emergent action (for instance Paraquat).

Planting densities.
In the last decades planting densities for production of palmito increased enormously. From 2500 $pl*ha^{-1}$ to the nowadays advised 5000 $pl*ha^{-1}$ (2 m between rows and 1 m between plants). Higher densities are possible but the ergonomic conditions for labourers with regard to the spines of the plant set their limitation. Many

times ca. 4000 pl*ha^{-1} now are planted to ease working.
ANAI (1986) recommends planting densities for palmheart production at 4,445 pl*ha^{-1} (1.5*1.5 m) on fertile soils on flat areas, 2,500 pl*ha^{-1} (2*2 m) on poor soils on flat areas and on fertile soils on inclined areas, and 1,600 pl*ha^{-1} on poor soils on inclined areas.

On big plantations (for instance *Agropalmito S.A.*) roads are made for tractors to collect the harvested palmitos (lower part of the stem). In this way only an average planting density of 3,700 pl*ha^{-1} is reached.

Intercropping.
On sites with a slope it is recommended to intercrop peach palm with species that cover the ground well. On fields that just are being planted with peach palms, crops like maize or beans are recommended (ANAI, 1986). In peach palm fields intercropping only is practised in the first or at most in the second year after transplanting. Later on, incoming solar radiation is too little for the intercrop plant to grow well. Also because after the first harvest and pruning, mulch layers will be made between the palms and intercropping for ground cover won't be needed anymore. Besides that, the intercrop may suffer from mechanical damage due to the large leaves of palmito dropped in the interrow.

Fertilization.
The high temperatures and precipation lead to quick decomposition of organic material in the humid tropics. Due to this high precipation, nitrogen is rapidly lossed by lixivication. Phosphate and potassium are or fixed in the soil or are leached. Because of this it is better to give smaller applications more frequent. Table 4.1 (see next page) gives recommended fertilizer doses for cultivation of palmito, when the crop is in production. Before this, the seedlings already obtained some fertilizers (usually a compound NPK fertilizer).

On the big plantations sometimes fertilization is under supervision of a specially employed administrator (application of fertilization and herbicides). This for instance is the case for *Agropalmito S.A.* and INDACO (a palmito plantation in San Carlos in the canton Sarapiquí). On these plantations very high amounts of fertilizers are given.

Table 4.1 Adviced fertilizer quantities ($kg*ha^{-1}*y^{-1}$) and application frequencies for a palmito plantation ($4,000\ pl*ha^{-1}$).

N	P_2O_5	K_2O	Source
300-400	200	150-300	ASBANA, 1981
3* 120	100	2* 100	MORA URPI et al., 1984
		275	ASBANA, 1985
4* 120	4*240	4* 120	ANAI, 1986
200-250	20	160-200	HERRERA, 1989
4* 125	4*150		AGROPALMITO, 1991

Small farmers give different amounts of fertilizers. Often it is stated that they only apply small amounts and then still only N-fertilizers, not enough to compensate nutrient flows from the fields (JONGSCHAAP, 1992). From a study of Jongschaap N-fertilization data of 15 farmers in the Atlantic Zone can be used to see how small farmers practise fertilization. The farmers all used NUTRAN (NH_4NO_3, 33.5% N) as N-fertilizer. Large variation exists among the data. N-fertilization rates varied from 31 kg $N*ha^{-1}*y^{-1}$ to 740 kg $N*ha^{-1}*y^{-1}$ (these data were the extremes of 11 data). The mean of these 11 data is 308 kg $N*ha^{-1}*y^{-1}$. This seems to be in accordance with some of the recommendations in table 4.1. Still some of the farmers did not apply enough. The highest N-fertilization data should be handled very carefully, because Jongschaap claimed that these data couldn't have been true. Fact was that most farmers knew which quantities to apply.

Weed control.
Weeds, especially *Gramineae* compete with peach palm for nutrients and space. When peach palms are young, growth can be delayed very serious. When a lot of *Gramineae* are present ROUND-UP normally is used as a systemic herbicide. When the area is weed-free, a pre-emergent herbicide can be applicated each 3-4 months. Herbicides are sprayed from a reservoir carried on the back.

Small farmers spray herbicides when necessary as well, especially ROUND-UP is used to control grassy vegetation.

Pruning.
For production of palmito, only a limited number of suckers is retained. Although at each plant 10-12 suckers are born, only 4-6

are retained (JONGSCHAAP, 1992). But it looks logic that under good management (fertilization), more suckers can be retained than these numbers. See table 6.1a for this (see page).
Copious leaves and bad or copious suckers are cut and left between the rows as a mulch layer. This pruning thus functions as control of number of suckers (growth rate) but also to maintain working space.

Because small farmers use less fertilizers than plantations, less suckers are retained on their fields.

Harvest.
First harvest of palmito takes place when some suckers have a stem diameter of ca. 15 cm (MORA URPI et al., 1984). At *Agropalmito S.A.* suckers are harvested already when the stem has a diameter of ca. 9 cm at the base. Because a palmito crop never is uniform (every "cepa" consists of various suckers in different growth stages), harvests have to be performed frequently (for example once in 1-2 weeks).
The harvest of palmito is done by hand. With a "machete" (large cutting knife) leaves are cut near the stem. The stem is cut just above the ground. Then outer leaf sheaths are separated and the palmito is cut at a distance of ca. 1 m from its base. This product has a fresh weight of ca. 1.5 kg. Yields on good plantations can exceed 10,000 palmhearts per ha per year.

Contrary to the high yields on the plantations, small farmers normally produce less palmhearts. In the already mentioned study from Jongschaap (1992) yield data were given for 15 small farmers.
Extremes were 2489 and 9800 palmhearts per ha per year. The mean was 6407 palmhearts per ha per year. Again these numbers have to be handled very carefully because these numbers have been collected in interviews.

Post harvest.
After harvest palmhearts have to be processed as soon as possible because their quality decreases quickly. This is due to the browning of the originally white palmheart tissue in presence of oxygen.
The palmhearts can be sold on the local market in unprocessed form or they can be sold to a factory where they are processed. The palmhearts are canned and exported to Canada, the USA or for instance France in Europa.

5 NUTRIENT CYCLE

Because organic material is oxidised at a very high speed when temperatures and precipation rates are high, the layer of organic material would decrease very quickly, when no new organic material would be added. Because of high precipation, leaching of the released nutrients is high. These disadvantageous conditions for the nutrient cycle are present in the Atlantic Zone of Costa Rica.
In farming systems the nutrient cycle (Fig. 5.1) is more open than in a natural ecosystem because nutrients are removed with harvested products from the fields. This loss has to be compensated by inputs if the system is to be sustainable in nutrients.
Herrera (1989) quantified the losses of nutrients when pejibaye is cultivated for palmito.

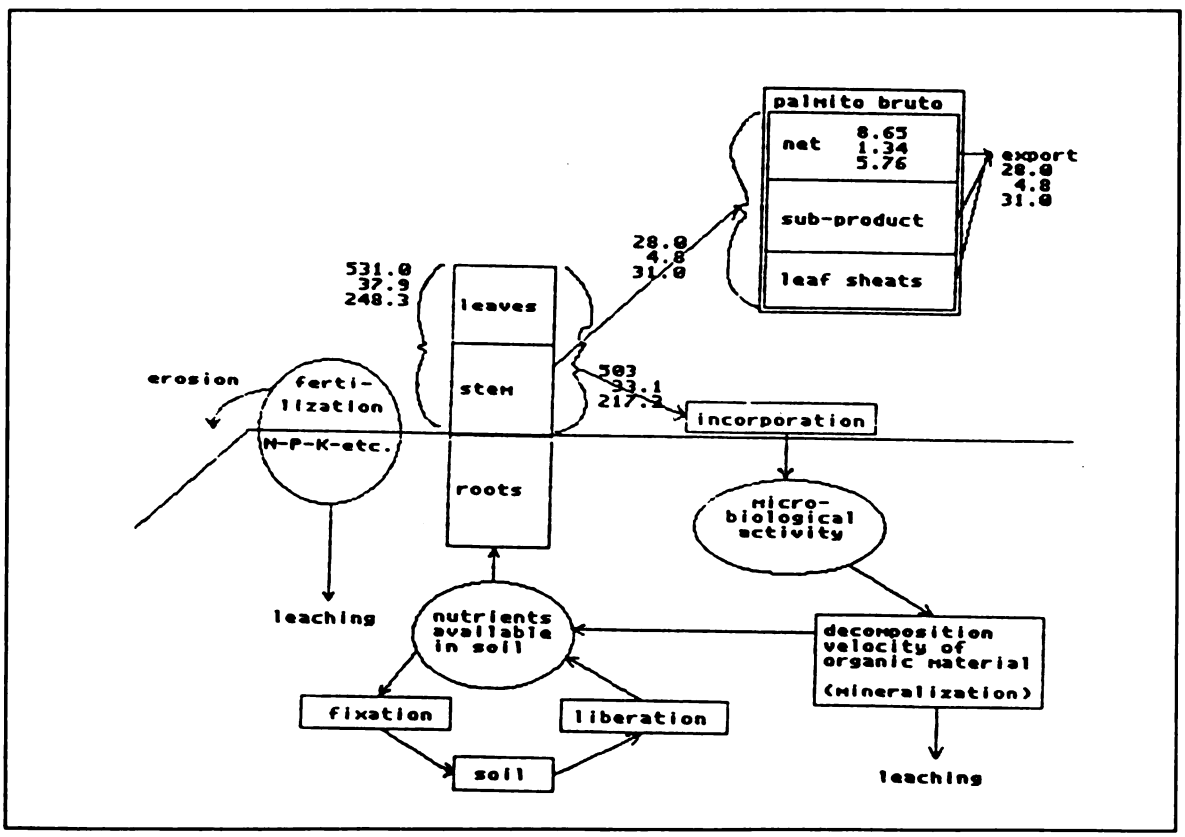

Figure 5.1 Nutrient cycle in a palmito cropping system (from Herrera, 1989). Removed nutrients respectively mentioned as N, P, and K in $kg*ha^{-1}*y^{-1}$, based on a planting distance of 3200 $pl*ha^{-1}$ and a yield of 9600 $pl*ha^{-1}*y^{-1}$.

He found out that only 28.0 kg N $*ha^{-1}*y^{-1}$, 4.8 kg P $*ha^{-1}*y^{-1}$ and 31.0 kg K $*ha^{-1}*y^{-1}$ were removed from the fields as bruto palmito (with still some leaf sheaths and parts of the palmito that won't be canned). When looking at the relatively low nutrient export from the fields it thus is evident that peach palm cultivation for palmheart is quite sustainable. This especially is true when compared to annual crops.

After considering the nutrient status of the soil, and the high leaching rate, Herrera (1989) came to the conclusion that fertilization in the Atlantic Zone of Costa Rica should be 200-250 kg N $*ha^{-1}*y^{-1}$, 20 kg P_2O_5 $*ha^{-1}*y^{-1}$ and 160-200 kg K_2O $*ha^{-1}*y^{-1}$. When looking at these fertilizer doses it becomes clear that this way of fertilization isn't sustainable at all. N-, P- and K-fertilization are respectively 8.9; 1.8; and 4.3-5.4 times higher than their removal from the fields as bruto palmito. These excesses will accumulate in the environment.

PART II:

6 A N-P-K FERTILIZER TRIAL FOR PALMITO

6.1 Needs for palmito research

Although already some research of fertilization of peach palm was done in Costa Rica, only little research on this subject has been carried out in the Atlantic Zone of this country. There still is a lot to investigate.

Recently the use of crop growth simulation models attracts a lot of interests. These models contain certain variables that, if all quantified, lead to predictions of the dependent variable. These models have the advantage of being adaptable to different situations, provided that the variables describe these situations (for example rainfall, temperature, soil fertility, etc.). These models thus can be used in a variety of areas.
Ir. D. Jansen is working on a simulation model for the development of peach palm plants. He uses among others important variables as number of suckers per plant, number of leaves per sucker, leaf area and soil fertility. With this model he, among others, wants to predict what the optimal number of suckers per motherplant is, given a certain level of soil fertility (in terms of nitrogen, phosphate and potassium content of the soil).
The last mentioned aim of Jansen's model is very important. Formerly palmito cultivators did approximately grow seven suckers per motherplant. If there were more, they were cut in a young stage. Given their relatively low fertilizer use, this was the optimal number of suckers. Nowadays with the proceeding investigation, especially on large plantations, new strategies are used. On the large plantation company *Agropalmito S.A.* all the suckers (10-12) are grown. To make that possible, they use more fertilizers. The model that Jansen is developing, will be a good help to decide which strategies are preferable under a given condition. When among others also account is given to fertilizer prices, an economic optimal strategy can be formed.
For this model it thus is necessary to know how the plant reacts to different fertilization levels. This is investigated and is written down in this report.

6.2 Aim and hypotheses for the N-P-K fertilization trial for palmito

The aim of this study is to determine how peach palms grow under different N-P-K fertility levels of the soil. To describe this growth, some plant characteristics are analysed. These characteristics are the ones which were thought to be influenced by the different fertilization levels. The hypotheses are:

- N-fertilization increases vegetative growth and thus vegetative size on a specific moment. Leaf area per sucker is thought to be increased, and when this also coincides with a proportionally higher total of nitrogen in the leaves (needed for the enzyme rubisco, which plays an important role in the proces of photosynthesis), it will lead to a higher photosynthetic production. And this thus will lead to an increase in dry matter weight ("positive feedback loop").
- Another plant characteristic which is thought to be influenced by fertilization is the height of where last leaf sheaths disperse (see figure 6.3). This is a measure for competition. Perhaps a higher fertilization will lead to an increase in height of where last leaf sheaths disperse. This because more suckers can deal with the competition for light (a growth limiting factor becomes less limiting) and thus can grow out more rapidly to greater heights. On the other hand when fertilization is increased, more suckers can be expected and this perhaps will lead to smaller growth rates of the individual suckers. In this case the opposite will be true.
- When the leaf area of the individual suckers is influenced by fertilization, this effect could have been caused by several fertilizer effects on leaf variables. Perhaps leaf variables as developing rate, number of living and dead leaves per sucker or just leaf areas of the individual leaves are influenced by fertilization. High leaf developing rate, high leaf area of the individual leaves and less dead leaves lead to a higher leaf area per sucker.
- Another very important plant characteristic is the number of suckers per motherplant. This is thought to be linked with the growth of the individual suckers. When there are many suckers per motherplant, the growth rate (here measured as leaf area and height of where last leaf sheaths disperse) of individual suckers is likely to be smaller. This because sources of light, water and nutrients have to be distributed

among more suckers. But on the other hand as fertilization is increased, competition between the suckers for nutrients becomes less, because nutrients are present in higher quantities (per sucker). Thus it is to be expected that a higher fertilization can partly undue the effect of a larger number of suckers per plant.

Very important in palmito cultivation is to know how fertilization influences plant morphology. Fertilization always is used to increase yields, but what precisely is influenced in the plant that could cause changes in previous mentioned plant characteristics or in direct yield increases? Some hypotheses on this are:

- Specific leaf area is influenced by fertilization. This characteristic is the area of leaf per dry weight unit (m^2/kg) of leaf. With this characteristic it is possible to say more about the expected increase in leaf area (as influenced by nitrogen fertilization). When there is a significant N-effect and N-fertilization works positive on the specific leaf area, this might be because of thinnering of the leaves or just a decrease in dry matter content per leaf area unit. A negative correlation can exist when the opposite cases are true. But perhaps there won't be a significant N-effect. In this case the ratio between leaf area and dry weight is not influenced by nitrogen fertilization. The increase in leaf area then goes hand in hand with the same relative increase in dry weight.
- Dry matter distribution over leaves and stem (dry matter percentages of total dry plantweight (above ground part)) are influenced by fertilization. This plantcharacteristic says something about the way in which assimilates are distributed in the plant. When d.m. of stem increases relatively to d.m. of leaves, the harvest index increases (assumed that the increased portion stem assimilates go to the yield sink, the *candela* (which is only a part of the stem), in a higher ratio than the former harvest index).
- Percentage dry matter of leaves is influenced by fertilization. Nutrients (N-P-K) are essential parts of dry matter. An increase in supply of these nutrients could lead to more dry matter per volume unit of leaf. But when the water content of the leaves rises proprtionally with d.m. increase, the percentage d.m. of leaves isn't changed. An other option is that no increase in d.m. percentage of leaves will be noticed at all.
- Percentage dry matter of stem is influenced by

fertilization. Furtheron the same cases as for d.m. percentage of leaves can be valid for the percentage of d.m. of stem.

Growth rate (rate of increase in dry matter of the stem and leaves) of peach palm is very important because the yielded product is vegetative. So a high growth rate (length and width growth) of the stem leads to an earlier harvest period (normally peach palm suckers are harvested when the width of the stem at its base has a certain value). In this study it is expected that fertilization increases growth rate (and thus yield per year). The growth rate of peach palm itself is not analysed because during the trial all the plants had to be kept intact (weighing of dry matter was not possible). But development rates (increase in number, area, height per day) are analysed:

- height increase of last leaf sheath per sucker
- Increase in number of suckers per plant
- Increase in actually present leaf area (cut leaves excluded) per sucker
- Increase in total formed leaf area (cut leaves included) per sucker
- Increase in total number of formed leaves per sucker

From these development rates only the first is thought to be directly positively correlated with growth rate. So the hypothesis is that the increase per day in height of last leaf sheath is positively influenced by fertilization.
The same hypotheses can be made for the other development rates. Only for the last development rate it is doubtful to expect a fertilizer effect because it can be the case that this rate only depends on temperature.

6.3 Used materials and methodology for the N-P-K fertilization trial for palmito

6.3.1 Lay-out of the fields

At the 16th of July in 1991 a Dutch student from the Wageningen Agricultural University, Raymond E.E. Jongschaap, had started up this fertilizer trial by transplanting the palmito seedlings in the field. This field is part of the *Agropalmito* company in Guápiles.
Before the trial began, the field had been waste land for about one year. After this it had been cleared.
According to local experts it was to be expected that among

growth limiting factors nitrogen and phosphate would be the most important nutrients to consider. Potassium would not be among the growth limiting factors (Jongschaap, 1992). Still potassium was added to this field. *Agropalmito S.A.* namely wanted to analyse the effect of potassium on the quality of palmheart. Thought was that potassium would increase the fibrousity.
An experiment had been set up with three levels (0, 1 and 2) of nitrogen (respectively 0, 336 and 672 $kg*ha^{-1}*y^{-1}$), three levels (0, 1 and 2) of phosphate (respectively 0, 408 and 816 $kg*ha^{-1}*y^{-1}$) and two levels (0 and 1) of potassium (respectively 0 and 360 $kg*ha^{-1}*y^{-1}$). These different levels were combined. To reduce the size of the field, a particular statistical approach had been used (confounded 3*3*2 factorial trial). This statistical procedure had been followed as described by Cochran and Cox (1957).
The confounded 3*3*2 factorial test is not described in this report. For this report it is not of importance because it just was a way of designing the field, that had been done by another student (Raymond E.E. Jongschap). And furtheron in this report an other statistical analysis method is used (see paragraph 6.3.6). This was done because not all the plants of the 3*3*2 factorial trial were analysed.
The field design is given in Appendix 6-I. The field consisted of 4 replicates. Every replicate consisted of all the possible N-P-K combinations (18). Every N-P-K combination existed 4 times in every replicate. This because plants were analysed 4 times at fertilization effects. This was done in different periods (4 harvest dates). This resulted in 288 plots (18 N-P-K levels * 4 harvest dates * 4 replicate combinations).
The 4 replicates had been placed perpendicular to the gradient of expected variation, related to the topographic relief in the field.
From the four harvest dates in the field, only the plants from the last harvest date are analysed in this report. Half November of 1992 (approximately 490 days after transplanting in the field) the originally transplanted plants of this fourth group had been cut down. The research in this report deals with the suckers of these cut plants.

6.3.2 Location of the field

The field had been designed so that the replicates were placed east to west. Rows also had been orientated east-west. Distance between the rows was 2.5 meters, and 1.0 meter in the row between plants (4000 $pl*ha^{-1}$). Every plot had 16 plants, placed in 4 rows of 4 plants of which the central 4 were harvested. The total area of the test field was 1.15 ha. At the southern side of the field a canal had been dug to drain the water coming from the adjacent houses.

6.3.3 Fertilization and management

The fertilizers were applied bi-monthly to reduce leaching of nitrate and fixation of phosphate and possibly also of potassium. Fertilizers were given in the form of NUTRAN (Ammonium nitrate- NH_4NO_3 (33.5% N)), Triple Super Phosphate (46% P_2O_5) and KCl (60% K_2O). Fertilizing was done with the help of labourers. Applications were given throwing a known volume of fertilizer (taking in account a constant specific weigth for each fertilizer) on the soil at ca. 20 cm from the plant. Specially made cups (made from tubes) were used with the required volume that were filled from carried containers. Per application the plants received 0, 42 or 84 g of NUTRAN, 0, 37 or 74 g of TSP and 0 or 25 g KCl.
When needed, weeds were removed by hand or by applying herbicides.

6.3.4 Measured plants in the field

In this research only is looked at 4 fertilizer combinations. These are:

N-P-K = 000 (N=0, P=0 and K=0 $kg*ha^{-1}*y^{-1}$)
N-P-K = 021 (N=0, P=816 and K=360 $kg*ha^{-1}*y^{-1}$)
N-P-K = 200 (N=672, P=0 and K=0 $kg*ha^{-1}*y^{-1}$)
N-P-K = 221 (N=672, P=816 and K=360 $kg*ha^{-1}*y^{-1}$)

Since regression formulas are made for plantcharacteristics depending on these fertilizer levels only (see paragraph 6.4), these N-PK codes were simplified. Phosphate and potassium were only given together, so no individual P- and K-level can be used in the regression formulas.
The N-PK codes that are used in this report, will be described as:

N-PK = 00 (N=0, P=0 and K=0 $kg*ha^{-1}*y^{-1}$)
N-PK = 01 (N=0, P=816 and K=360 $kg*ha^{-1}*y^{-1}$)
N-PK = 10 (N=672, P=0 and K=0 $kg*ha^{-1}*y^{-1}$)
N-PK = 11 (N=672, P=816 and K=360 $kg*ha^{-1}*y^{-1}$)

Because there also are 4 replicates, a total of 16 plots have been analysed.
These 4 fertilizer combinations have been chosen because these were the most likely ones to show significant differences in

examined plant characteristics. With these combinations it is possible to see if there is a N-effect, a PK-effect and a N-PK-interaction effect.
Because three measurements at different times were done, the suckers of the motherplants had been marked with coloured ribbons. Each plastic ribbon had a specific colour. Combination of ribbons with different colours provided sufficient possibilities to mark the different suckers. Ribbons were fastened on the leaf raches.
In this way it was garanteed that the plants weren't confounded.

6.3.5 Measurement of plant characteristics

Analysed were the fertilizer effects on several important plant characteristics at different times, and the dynamics (developing rates) of these over a certain time span. Measuring periods were:

2-3-1993 until 21-3-1993
13-4-1993 until 21-4-1993
3-6-1993 until 16-6-1993

To minimize treatment effects as a result of different measurement times within the measuring periods, measurements within a replicate were completed before moving to the next one. In this way these possible treatment effects because of different measurement times are confounded with block effects, that can be separated by statistical analysis.

Plant characteristics were measured in a non-destructive way. Plants had to be kept alive for collecting data for the second and third measurement period. The measured plant characteristics are:

- Leaf area
- Leaf developing rate
- Number of living and dead leaves per sucker
- Number of suckers per motherplant
- Height of where last leaf sheaths disperse

These plant characteristics are very important because they all have direct or indirect effects on palm heart yields.

With a special formula developed by Hardon, found in an article of Clement et al. (1985) an estimation can be made of leaf area of older leaves in peach palms. This formula is based on the idea that leaf area is related to length and width of certain leaflets. Leaflets of peach palms are organized in groups of two at its rachis (figure 6.1b). Length and width of the 6th, 10th and 14th leaflet of the right side, and of the 8th, 12th and 16th of the left side must be measured and be used in equation 6.1. The value of ß had been calculated to be 0.72 (Clement et al., 1985).

$$LA = \beta * (l * w)_{6R-16L} * n \qquad \textbf{Eq. 6.1}$$

with: LA = leaf area (cm^2) of pinnate leaf
β = regression coefficient
l = mean length of 6 leaflets (cm)
w = mean width of 6 leaflets (cm)
R = right
L = left
n = total numbers of leaflets at leaf

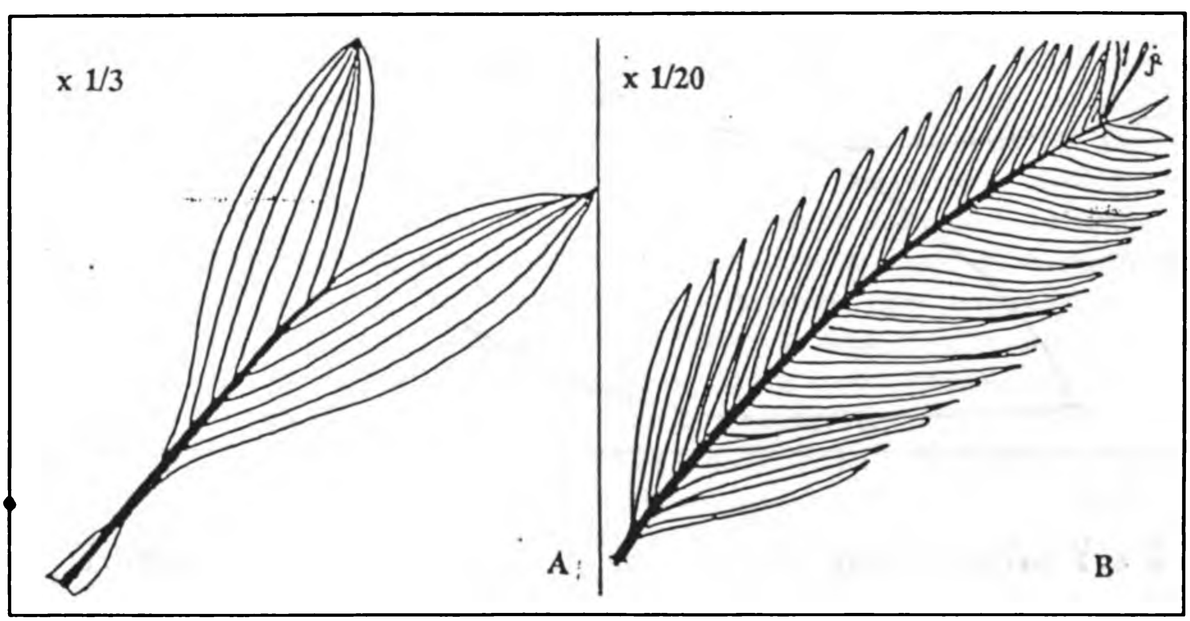

Figure 6.1 Leaf types of *Bactris gasipaes H.B.K.*. Bifid (a) when young and pinnate (b) when older.

Because young leaves of the peach palm have a different form (figure 6.1a), an other equation is necessary to estimate leaf area. Jongschaap (1992) developed an equation for this (equation 6.2). He found that the value of the regression coefficient ß was 1.25 and the correlation coefficient then was 0.982. The used variables are the length and width of one part of the bifid leaf (figure 6.2)

$$LA = \beta * (W * L) \qquad \textbf{Eq. 6.2}$$

with: LA = leaf area (cm^2) of bifid leaf
β = regression coefficient
W = width (cm)
L = length (cm)

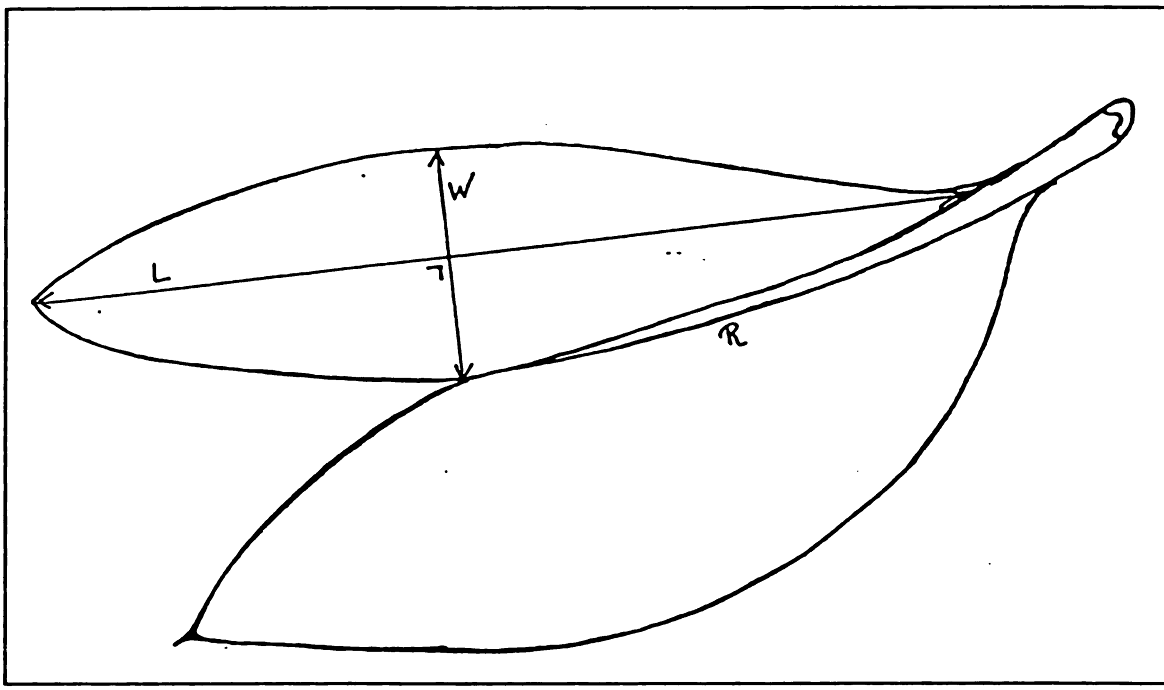

Figure 6.2 Palmito leaf (bifid) and place where leaf parameters were determined.

With these two equations estimations have been made of the leaf area of the different sucker leaves. By adding up the different leaf areas per sucker, the leaf areas per sucker were calculated. Two types of leaf areas per suckers have been measured in this way.
The <u>actually present leaf area per sucker</u> is the sum of the leaf areas from the individual palmito leaves that were present when measured. Leaves cut by the *Agropalmito* workers thus weren't included. This type of leaf area per sucker is representative for the management of the palmito fields of *Agropalmito S.A.*.
The other type included the cut leaves as well. To do that, the

leaf areas of the cut leaves have been estimated on the basis of the former and latter leaves. This total leaf area per sucker is representative for undisturbed growth. One critical note has to be placed about this latter leaf area type. When the cut leaves wouldn't have been cut, the younger leaves probably would have been bigger or smaller because the source of assimilates would have been bigger (more assimilates) respectively the sink would have been bigger (less assimilates for newly formed leaves).

The developing rates were calculated by using measurements of lengths of leaves and spears. A peach palm forms a new leaf by stretching this leaf out as a spear. At a certain moment this leaf unfolds and stretches out more.
For measuring leaf developing rates, 3 times of measuring are needed (with sufficient time between them: ca. 1 month). The first time only the length of the last spear (or when not present, the length of the last formed leaf) was measured. The second time the length of this spear/leaf was measured again. This length is thought to be maximal because it is assumed that the stretching of the spear/leaf was finished. On this second time also the length of the new formed spear/leaf is measured. At the last point of time the (maximal) length of the at second time measured new formed spear/leaf was measured again. By comparing the relative lengths (actual length/maximal length) of the first and second time, it was possible to see how much the relative increase was of the leaves. Because the lengths of the time intervals between measurement times 1 and 2 were known, the leaf developing rates could be calculated over these first time intervals. Because temperature data (Appendix 6-II) also were available, the leaf developing rates also could be calculated as temperature sums. These temperature sums are calculated as cumulative mean day temperatures. No basis temperatures are used (or put differently: they are supposed to be 0 °C).

The number of living and dead leaves simply were counted even as the number of suckers per motherplant.

The height of where the last leaf sheaths dispersed, was measured on the place as illustrated in figure 6.3. The last (newest) and second-last formed leaf sheaths had been of unfolded leaves and not of possible spears present.

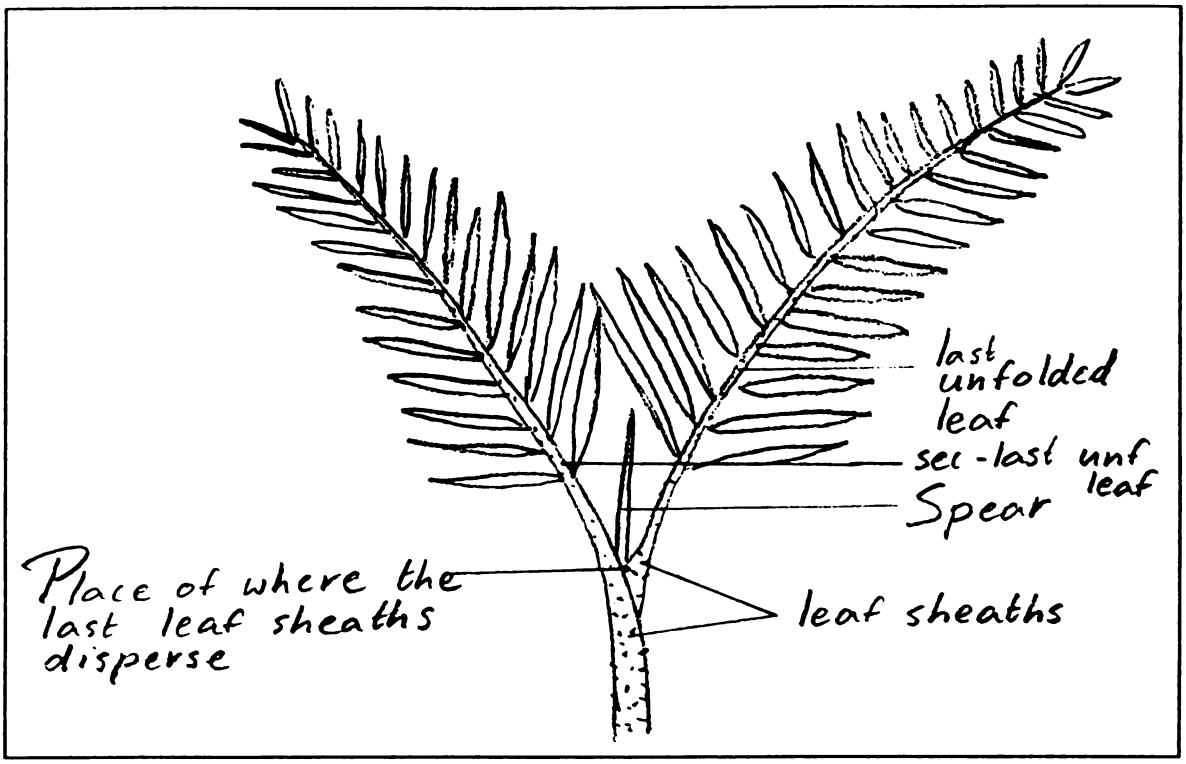

Figure 6.3 The place of where the last leaf sheaths disperse.

On 21-6-1993 (after measurements of non-destructive growth) plantcharacteristics were measured in a destructive way. Measured were leaf area, and fresh and dry weight of leaves and stem. As derivatives the following plant characteristics can be found:

- Specific leaf area
- Leaves (d.m.) as percentage of total dry plantweight (above ground part)
- Stem (d.m.) as percentage of total dry plantweight (above ground part)
- Percentage dry matter of leaves
- Percentage dry matter of stem

From all the four replicates, four suckers were harvested from each of the four treatments included (see 6.3.4). These four suckers belonged to different length classes (height where last leaf sheaths disperse):

level 1: 0 - 25 cm
level 2: 25 - 50 cm
level 3: 50 - 75 cm
level 4: 75 - >75 cm

From all these suckers certain characteristics were measured (see also appendix 6-III). First, height (exact) of where last leaf

sheaths disperse, diameter of stem at base, and fresh weight of the whole sucker (without roots) were measured accurately.
From the two suckers from the two lowest length classes, all leaves were measured. But from the two bigger suckers, only the second-last leaves were measured.
The suckers then were separated into stem- and leafparts. The leaf part consisted only of leaves without the leaf rachis that divides the leaf into two parts. The stem then consisted of the rest (stem itself and leaf raches). Fresh weights were determinated for the stem-and leafparts. Then a subsample was made from the stempart (after chopping and mixing it, to make a representative subsample) for determination of d.m. content (approximately 3 days drying in an oven at a temperature of 75 degrees Celsius).
Furtheron leaf (sub) samples were made. The samples of the two smallest suckers consisted of all their leaves.
The subsamples of the two bigger suckers consisted of representative (chopped and mixed) parts of all their leaves (except their second-last leaves). From these subsamples leaf area also was measured, because of the collection of specific leaf area information. For all these subsamples the d.m. content was determined (approximately 3 days in the oven at a temperature of 75 degrees Celsius).

6.3.6 Way of analysis of observations

For analysing the observations, a stepwise multiple regression analysis method is used. This method is executed with the statistical program *"SPSS/PC+"*. With this analysis method a regression formula is made to show the relation between the measured plant characteristic and the factors that have significant influence on it. The regression formula always consists of a constant (which shows the value of a plant characteristic in case no fertilizers are applied) and one or more regression coefficients. See equation 6.3 for a general regression formula.

$$PC = constant + (rc_1 * IF_1) + (rc_2 * IF_2) + etc. \qquad \textbf{Eq. 6.3}$$

with:

PC	=	plant characteristic (matching units)
$constant$	=	constant (PC matching units)
rc_1	=	first regression coefficient
IF_1	=	first influencing factor
rc_2	=	second regression coefficient
IF_2	=	second influencing factor

With this method an independent variable is entered in a first grade regression model (one regression coefficient and influencing factor) if it meets the required demand of having a probability of F-to-enter (significant F value) less then 0.05. This means that the F-value should be higher than a specific value (which depends on the number of observations/measurements). The probability interval of the independent variable (factors which can have effects, like for instance N-fertilization) then is [1-significant F value , infinity>. When the first independent variable is entered (met the required demand), the analysis method looks if there are others that also can be entered (with the same requirement). When that happens, this always leads to an increase in the correlation coefficient between the dependent variable and the independent variables (increase in Mult. R_{model}): the predictions of the model match the observations better.
But it also is possible that no independent variable at all will be entered. Then there is no significant effect of an independent variable on the dependent variable.

6.4 Results

Results of the statistical analysis are given in the tables 6.1a till 6.3, in appendix 6-IV.
Tables 6.1a, 6.1b, 6.1c and 6.3 show the results of the stepwise multiple regression analysis of measurements taken in the first measuring period (2-3-1993 until 21-3-1993). The measurements of the numbers of harvested suckers per field (table 6.1a and 6.1b) though, were done in the beginning of the third measuring period (3-6-1993).

Number of leaves.
From table 6.1a it can be seen that nitrogen has a significant effect on almost all plant parameters, except for <u>dead leaves per sucker</u>, <u>total number of formed leaves</u>, and <u>leaf formation time</u>. These latter two seem to be in accordance with each other. This

because total number of formed leaves is determined by leaf formation time. So when no significant fertilizer effect on leaf formation time is found, this automatically means that the total number of formed leaves is influenced by fertilizers neither. For dead leaves per sucker a N-PK interaction effect was found significant. When N and PK fertilizers both are given in higher quantities, the number of dead leaves per sucker increases.

From the regression coefficients of the independent variable N-level (table 6.1a and 6.1b) it can be seen that the nitrogen fertilization has a high impact on the peach palm. A lot of plant characteristics ("dependent variables") are influenced by it.

Number of suckers per motherplant.
The total number of suckers per plant increased from 6.29 to 7.98 when 672 kg $N*ha^{-1}*y^{-1}$ was given. This led to 6760 suckers per ha more in a period of ca. 600 days after transplanting in the fields!
But even the PK-level (816 kg $P*ha^{-1}*y^{-1}$ and 360 kg $K*ha^{-1}*y^{-1}$) had a great significant effect. The number of suckers per plant increased from 6.29 to 7.79 (an increase of 6000 suckers). When full fertilization was given (N-PK=11), a non-interactive increase of 3.19 suckers per plant was found (leading to a total of 9.48).

Leaf area per sucker.
The actually present leaf area and the total leaf area per sucker nearly doubled under the influence of the nitrogen fertilization (672 kg $N*ha^{-1}*y^{-1}$). They respectively increased from 9669.49 cm^2 to 18076.26 cm^2 and from 9926.42 cm^2 to 19075.04 cm^2. These increases in leaf area stemmed for a great part from the increases in leaf area from the last and second-last leaves.

Height of place where last leaf sheaths disperse.
The height of place where the last leaf sheaths disperse also was positively influenced by nitrogen fertilization (672 kg $N*ha^{-1}*y^{-1}$ led to approximately 21.5 %increase in height). The formerly stated hypothesis that a higher fertilization (N-level) would lead to more and higher plants, is proved. The nitrogen fertilization effect thus was so strong that it not only increased the number of suckers per plant, but also fastened their length growth.

Number of harvested suckers.
The number of harvested suckers (at harvest date (2-6-1993)) per

field (4 plants) increased when the nitrogen fertilization level increased. According to table 6.1a, when 672 kg $N*ha^{-1}*y^{-1}$ was given, 2.89 suckers more could be harvested. This is more than a doubling of the number of harvested suckers at the harvesting date! This already was to be expected. At higher N-level there are more suckers per plant, which in turn have higher leaf areas, which will lead to more assimilates and thus faster growth, although this faster growth couldn't be verified. This faster growth leads to a higher point of where the last leaf sheaths disperse. This height doesn't say something about competition relations only, but also is positively correlated with the diameter of the stem at the base (when the peach palm (in its juvenile phase) increases its height, it also increases the diameter of its stem at the base). Because the diameter at the base is the criterion for harvesting, it thus is explained that a higher N-level leads to more harvestable suckers in a shorter period.
Table 6.1b shows that the number of harvested suckers per field (per 4 plants) only depended on the nitrogen level between 0 and 336 $kg*ha^{-1}*y^{-1}$. Above 336 $kg*ha^{-1}*y^{-1}$ the number did not increase anymore because of the N-level. Following this analysis, there thus exist a N-level optimum below 672 kg $N*ha^{-1}*y^{-1}$, but it can't be said where exactly (because of too few nitrogen levels). Note that the multiple R_{model} from the model in table 6.1b is a little lower than the model in table 6.1a. Both relations (table 6.1a assuming a linear relation and table 6.1b assuming a non-linear relation) between number of harvested suckers and N-fertilization are presented graphically in Figure 6.4.

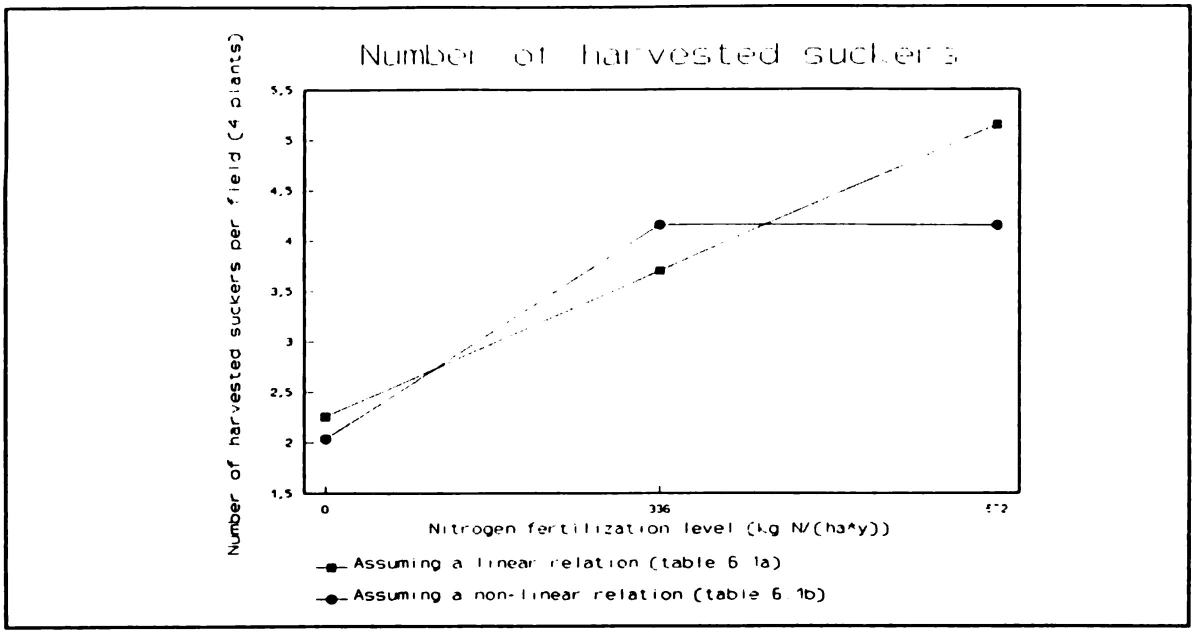

Figure 6.4 Number of harvested suckers per field of 4 plants, depending on nitrogen fertilization level.

Table 6.1c originated from the assumption that averaging of the dependent variables over all the suckers from the four individual plants would lower the standard error of the models. Because of this, the R_{model} increased.
In physiological sense the averaging was permitted because of the fact that suckers within a plant and plants within a field influence each other (for example: big plants will overshadow others, that because of that will stay little (competition for sunlight)). Averaging reduced part of this variation.
Table 6.1c differs from table 6.1a aside from different numbers, in several other points. Contrary to table 6.1a no single N- and PK-level effect on the mean number of suckers per plant was found, and no N-PK interaction effect on the mean number of dead leaves per sucker.

The results of the dynamic growth analysis is presented in table 6.2. The rates of development and growth (differences between two successive measuring periods divided by the period between these measuring periods) were calculated between the three measurement times. It seems very strange that an analysis of variance (3 classes with interaction) showed hardly any significant effects of the fertilization. Especially N-effects could have been expected. This even seems more logical when table 6.1a and 6.1c are regarded. The leaf area of the second-last and last leaf

are highly significantly influenced by N-fertilization. A higher leaf area growth rate thus seems logical for higher N-fertilization.
An explanation is that the rates show a very big variation. In this way the residual sum of squares becomes real big.

Rate of increase in height of where last leaf sheaths disperse and rate of development of total formed leaves.
Four significant effects are identified. The rate of increase in height of where last leaf sheaths disperse (for both periods) and the rate of development of total formed leaves (for both periods).
But these were significantly influenced by interaction effects and differences between replicates were large. So no interesting influences are found.

As can be seen in table 6.3, there are no direct fertilizer effects on the specific leaf areas, dry matter distribution over leaves and stem, dry matter contents of leaves and stem. These variables only are dependent on length class levels. However, because the length class level (height of place where last leaf sheaths disperse) is influenced by N-fertilization, the mentioned variables are influenced indirectly by N-fertilization.
Because there was no significant N-effect on specific leaf area, the increase in leaf area as a result of nitrogen (paragraph 6.3) had to be proportionally with increase in dry matter of leaves.
Specific leaf area decreased when suckers grew bigger. Thus leaf area per weight unit of dry matter of leaf decreased. This is a result of the increase in dry matter of leaves (when leaf area increased less than proportionally).
The leaf percentage of above-ground plant decreases, and stem percentage of above-ground plant increases with length growth.

6.5 Conclusions and discussion

With the results of the N-P-K fertilization trial the hypotheses can be verified or rejected and conclusions can be made on peach palm growth as influenced by fertilization.

- N-fertilization increases vegetative growth (and thus size at a specific moment). Leaf area per sucker is increased.
- The height of where last leaf sheaths disperse, is positively influenced by N-fertilization. This height increases with ca. 21.5 % when fertilized with 672 kg $N*ha^{-1}*y^{-1}$ (when grown under growth conditions as in the test field used in this research).

- Increased total leaf area per sucker, under a higher N-level, is a result of leaf area increases of the individual leaves. This is proven by the results on the number of living and dead leaves. N-fertilization had no significant effects on number of living and dead leaves, so increased total leaf area per sucker couldn't have been a result of a higher number of present (living) leaves. Also the results of the leaf areas of last and forlast leaves show a higher leaf area of (at least the newest formed) individual leaves, when fertilized with nitrogen.
- The number of suckers per motherplant increases significantly with ca. 3.19 suckers when full N-PK fertilization is given (672 kg $N*ha^{-1}*y^{-1}$, 816 kg $P*ha^{-1}*y^{-1}$ and 360 kg $N*ha^{-1}*y^{-1}$).
  No significant N-effects are found on growth rate of leaf area and on height of where last leaf sheaths disperse; so it can be concluded that the higher number of suckers per motherplant don't coincide with lower growth rates of the individual suckers.
- The number of harvested suckers on the first possible harvest date is greatly positively influenced by N-fertilization. In an earlier stage of crop growth, more big plants are formed.
- The growth rates in this trial were not influenced by fertilization with nitrogen alone. Interaction effects were found to be significant. It looks really strange that no significant N-effects had been found. This especially looks strange when leaf area of the suckers is regarded. N-level positively influenced this leaf area (the newly formed leaves of the suckers were highly positively influenced by N-fertilization), so higher growth rates were expected in case of N-fertilization.
- Specific leaf area is not influenced by fertilization. The ratio between leaf area and dry matter weight stays the same under different fertilization. But now it is known that N-fertilization positively influenced total leaf area per sucker, the amount of dry matter in the leaves of N-fertilized plants had to increase proportionally. So it can be concluded that N-fertilization positively influences dry matter amount in the leaves.
- Dry matter distribution over leaves and stem (dry matter percentages of total dry plantweight (above ground part)) are not influenced by fertilization. The assimilates thus are distributed in the same way whether or not fertilized. Nonetheless the absolute amount of assimilates which go to leaves and stem is influenced by fertilization. The conclusion can be made that N-fertilization positively

influences the dry matter amount of both leaves and stem. This can be proven by the fact that N-fertilization positively influences dry matter production of leaves (this is derived from the facts that the leaf area per sucker is increased by N-fertilization and SLA is not influenced by N-fertilization). Because assimilate distribution between leaves and stem stays the same, dry matter of the stem has to be increased under N-fertilization too.

- Percentage dry matter of leaves and stem are not influenced by fertilization.
- Unlike the fact that fertilization didn't influence the specific leaf area, dry matter distribution over leaves and stem (dry matter percentages of dry plantweight (above ground part)) and the percentage of dry matter of leaves, these plant characteristics all were influenced by their height level (height of place where last leaf sheaths disperse). Height increase goes hand in hand with a lower specific leaf area, a relatively lower distribution of dry matter over leaves compared to stem. The percentage dry matter of leaves increases also with height increase.

Some discussion points of the practical work of this trial: the field work and the measurement of plant characteristics can be made:

- *Bactris gasipaes H.B.K.* is a land race. This means that the plants of the crop are not uniform, but are genetically different. In this way differences in plant characteristics not only are caused by fertilization, climate, age, etc. but also by their genetic potential. In the fertilizer trial young plants were planted in the fields at random, so no differences between replicates were made.
- While walking in the field of the fertilizer trial, a worker of the *Agropalmito company* was seen fertilizing this field. This means that fertilization levels in reality were different from the ones described in this report. Hopefully this "extra" fertilization had not been done more times in this field. But still, as can be seen in the results, fertilizer effects could be recognized.
- Measured plant characteristics were the numbers of total formed leaves and dead leaves. The numbers of dead leaves were very hard to count. Many times these leaves disappeared already, and scars of the leaf sheaths had to be sought. Probably some mistakes in measuring the number of dead leaves have been made due to the complexity of the work.
- For measuring of total formed leaf area per sucker, estimates

had to be made for cut leaves. This cutting was done by *Agropalmito* workers as part of the management of the field. Sometimes cut leaves could be identified (leaf raches of cut leaves and of the part still present at the plant matched). Other times cut leaves could not be identified. The areas of these cut leaves then were estimated as the mean between former and latter formed leaves. In this case estimation led not to very accurate leaf areas. But when these inaccuracies of the cut leaves are compared with total leaf areas per sucker, these inaccuracies are small.

- In this report harvested numbers of suckers were analysed. The total yield weight and the weight of the individual yield products of course would have been much more interesting. The analyses of these plantcharacteristics were planned. But when the harvesting would start, the *Agropalmito company* workers already had harvested the suckers.
- The formulas used to estimate leaf areas of the leaves normally have to be checked with reality (for example when measured with a leaf area measuring device). This was done, but unfortunately in a wrong way. Leaf area formulas were checked per sucker. But these suckers had the two leaf types (bifid and pinnate). So real leaf areas (measured with the device) were compared with leaf area of the whole sucker. Instead of this the individual formulas should have been checked.

PART III:

7 DEVELOPMENT PROJECT "CARE"

In the period from the half of July until the half of August in 1993, a practical period was done at the development project *CARE Internaciónal en Costa Rica* in Upala (CR).

7.1 History and scope of *CARE*

CARE is a private development non-profit organization, is unpolitical and doesn't assume any religions. It was created in the USA in 1945, after the second world war. The aim was to help the countries which suffered hard from the war. So for instance, "CARE PACKAGES" with food, medicaments and clothes were sent to suffering families. After some time *CARE* redirected its objective to help all countries who need it (mostly in the third world). Nowadays *CARE* works in 80 countries, including Costa Rica.

CARE has been operating in Costa Rica since 1959. It started activities as food, health and agricultural programs and provided help in emergencies.
CARE works with people with low incomes and access to resources as for exemple capital and equipment. Its concept is:
"Ayudar a la gente a ayudarse a si misma" which means that it tries to help the people to help themselves.

7.2 *CARE* in the Northern Zone of Costa Rica

7.2.1 The Northern Zone of Costa Rica

Since 1990 the organization is working in the Northern Zone, which consists of the cantons ("cantones") of Upala, Guatuso, Caño Negro de Los Chiles in Alajuela and Santa Cecilia de Santa Cruz in Guanacaste. The zone thus borders Nicaragua (see figure 7.1).

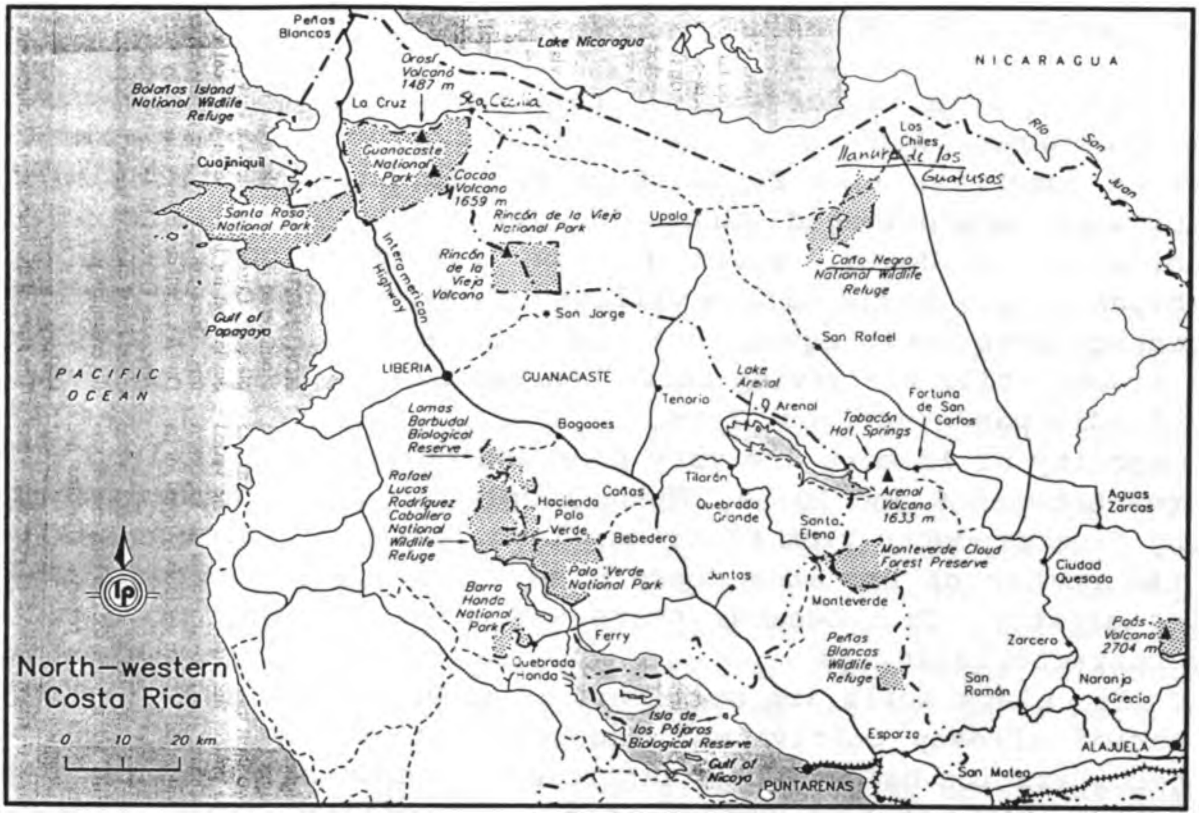

Figure 7.1 The Northern Zone of Costa Rica.

7.2.2 Climate

According to Sanchez Chinchilla (1981) the climate in Upala is tropical with a dry period. Rainfall is between 1600 mm and 3200 mm. The dry period starts in December/January and ends in May/April. In these months only a very small percentage of annual rain falls (ca. 5%).

When going more to the west, the dry period increases and rainfall is less. Also annual mean temperatures rise. In the east the opposite is true.

7.2.3 Soil and vegetation

Soils in the project zone are characterized as being alluvial, volcanic or soils developed on old eroded terraces. Their quality differs greatly. Their drainage can be good to very bad on the old eroded terraces. Fertility depends among others on the age of the soil.

Vegetation can be typified as tropical rainforest and tropical forest. Nowadays a big area is covered with grass and trees.

7.2.4 Farmers and land use

The Northern Zone is for a great part inhabited by immigrants from Nicaragua. And in a lesser extent from other Central American countries like El Salvador and Honduras. Costa Rican inhabitants approximated that the percentage of Nicaraguan inhabitants in Upala, would not be far from 90% of all inhabitants. And in the little villages closer to the border this percentage even would equal 100%. In some regions, the original inhabitants still are living there. An example is Guatuso, where many "indiginas" (natives) live.
The majority of farmers are very poor and only posess land with an area between 5 and 10 ha. These people for a great part are living from products from their own land (self-sufficiency).
But the number of hectares doesn't say very much. The quality varies greatly. This because there was great variance between land characteristics as:

- Soils: black soils are more fertile than red soils.
- Period already cultivated: Because most of the times the fertilization had not been sufficient to compensate nutrient losses, the nutrient status of a field decreased with time of cultivation.
- Slope: Some fields were situated at a slope. This gave erosion problems and serious implications for crop cultivation. Also light intensities played a role. The slope could be at the sun or at the shade side.
- Drainage: There was a very great variance between fields on basis of drainage status.
- Altitude: This has great implications for temperature and crop cultivation.

While visiting fields it became especially evident that there was a big diversity in cultivated crops at the farmers fields. This probably partly can be explained by the variance in land characteristics of the farmers fields. An other explanation is that the farmers are to a great extend self-sufficient: with such a pluriformity in immigrants and probably their food preferences this led to such a great variance in food crops.
The following crops were grown on the farmers fields:

- *Tuqisque*: A tuber crop that is very impotant for own use.
- *Frijoles*: Black beans that are sold and used for own consumption.

- *Maíz*: Maize, used for selling and own consumption.
- *Arroz*: Rice, used for selling and own consumption.
- *Banana* and *plátano*: For a great part for selling and for a lesser part for own consumption. In contrast with the Atlantic Zone of Costa Rica, in the *CARE*-project zone *bananeras* (large scale bananaplantations) are not present.
- *Café*: At the higher situated fields sometimes coffee can be found. This is a tipical cash-crop.
- *Naranjos*: Some bigger farms grow oranges for an orange juice company.
- *Zandias*: Water melons. This crop is cultivated at a lot of farms because they get high prices for it. An excellent cash-crop for a lot of farms.
- *Cacao*: Cacao also serves as a cash-crop although harvests aren't very good.
- *Teka* and *melina*: These two trees are thought to be good longer term investments. *Teka* (teak) is a good and relative fast growing tree of which the wood can be sold to some big corporations. *Melina* is a tree of which the wood is used for toilet paper. Both trees are important cash-crops, although untill now not many farmers grow them yet (probably because they have shorter term goals).
- *Pasto*: Some bigger farms grow grass and keep cows. But most smaller farms don't do that.

7.3 Objections and means of *CARE* in the Northern Zone

The project in this northern zone is a *PACCO*-project (*"Projecto de Agricultura y Crédito Comunal"*). A *PACCO*-project interpretes problems of communities as problems of low income. There final objective is **to raise the incomes of the families in a sustainable way.** To obtain this situation, the following is necessary:
- The participants must obtain a capacity to control their economic activities and their resources (communally as well as individually).
- They must improve their production and commercialization in their economic activities.
- Where it is possible, they must develop other economic resources as well.

These effects which are thought to be directly resulting in the final objective, are obtained by the execution of four components:
- <u>Communal organization:</u> The community has to control her

developed property and therefore needs to be prepared for this. The project searches for skill in the community so that the community learns their problems and can organize itself to solve these. To make this possible, the participants have to organize themselves in committees. For example a committee for credit or an intercommunal committee for commercialization of their products.

- <u>The incorporation of women in the development proces:</u> Although many problems related with the traditional role of women in communities can't be solved, the project tries to aim at the women as well because they too can generate incomes.
- <u>Development of small-scale economic activities:</u> This includes to help the small farmers or to help to develop alternative economic resources for women. Both ways have an educative character. In existing activities, the education is focused on diffusion of technics and knowledge. For example to raise a farmers production or to raise standards of health. In non-existing activities, the emphasis is on realization of studies of feasibility.
- <u>Formation of a communal fund for credit:</u> The project tries to establish a fund within the community that works quickly and is easily accessable for financing small-scale economic activities.

Actually *CARE Internaciónal en Costa Rica* established like this in 42 communities. But the *PACCO Zona Norte* has its own particularities as well:

- The project promotes untraditional crops as "pimienta negra" (black pepper) and "palmito de pejibaye" (palmito). They provide a higher income than the traditional crops as "maíz" (maize) and "fríjoles" (black beans). They will look for and investigate other promising export products as well (for example "*maracuya*" (passion fruit)).
- The projects extensionists helped with their technical assistence and "capacitación" ("know how") to grow plants in "viveros" (plant nurseries) in the *PACCO*-communities. Furtheron, the project arranged transportation for plants.
- The project cooperates with others aswell:
  * *Projecto Zona Norte (PCZN)*
  * *Ministerio de Planificación Económica (MIDEPLAN)*
  * *Instituto de Desarollo de Agricultura (IDA)*
  * *Ministerio de Agricultura y Ganaderia (MAG)*

The project is planned to operate for 3 years and is financed by

USAID and receives an amount of US$ 1,481,481. Further on earns the project itself something with profits generated at the *viveros* with black pepper and palmito.

7.4 The way of operating of *CARE* in the Northern zone

7.4.1 Project organization

The project staff of this project consists of 1 project coordinator, 1 subcoordinator (organiser), 1 secretary and 15 extensionists.
The project coordinator stays directly in contact with the *CARE*-office in San Jose which is the central office for all the *CARE*-projects in Costa Rica. The subcoordinator arranges field meetings and makes it possible that the extensionists can do their work.
The extensionists visit farmers and do the "fieldwork". Each extensionist works in his own particular region within the project zone.
An extensionist visits a community and invites the so called "*Asociación de Desarollo*" (association of development) to a meeting in which a project proposition is made. This "*Asociación de Desarollo*" is an association of community inhabitants who function as representatives from that community. Every community has such an association. It gets money from the government and several institutions. With that money they can build canals, roads, etc, so that the villge benefits from that.
When the project proposition is accepted, meetings are organized in the community. A "*Comité de Crédito*" is elected by the "*Asociación de Desarollo*". This is a committee that makes sure that the participants pay back their loans and obtained material as fertilizers and plants. Later on the committee can invest its obtained capital in new material and can give loans to the participants of the project. The committee consists of a president, a treasurer, a secretary, two *vocales* (voters who help making decisions), a subcommittee consisting of 3 guarders of the money (*"Comité de Vigilancia")* and a *"fiscal"* who stays in contact with the public ministry.
During the meetings of the extensionist with the community, the extensionist tries to convince the farmers to participate in the project. When they do, the project delivers the needed material as plants, fertilizers, etc. During growing the plants, the farmers are visited regularly and are supported with advices by the extensionists. When the farmers earn money during their yields, they have to pay back their loans to the "*Comité de*

Crédito".

As remarked earlier, the project aims to promote the growing of palmito, black pepper and other typical cash-crops. When visiting the project (half of July until the half of August in 1993) the project still was in a phase of planting and promoting *palmito de pejibaye* and black pepper. Also an experiment with *maracuyá* was prepared.
The aims of planting a total area of 1200 ha of palmito and 15 ha of black pepper among different farmers were likely to be achieved. In case of palmito the promotion almost was finished. The phase shifts further away from plant nurseries (*viveros*) to planting in the fields. It was hoped that the planting in the fields would be ready in short time. The activities with black pepper however still were in the phase of promotion and plant nurseries. And in case of *maracuya*, the terrain for the experiment was almost ready.
The organizations of communities was ready.
The future plans were to increase the cultivated areas with well performing crops and especially with crops for industrial ends and for export purposes.

7.4.2 Field practices in the project zone

In this paragraph field practices of the farmers and some impressions and problems will be described. These impressions were formed during a period of only one month, of which on only 10 days approximately the fields were visited by the author. So it is possible that generalizations were made on basis of coincidences.

When farmers wanted to participate in the project, they obtained among others plant material (palmito seedlings), fertilizers and when needed a sprayer with herbicides. After harvests the used material would be paid back. This thus functions as a kind of credit system that goes further than only a bank and in the same time can excercise some control over the agricultural production and thus over the payback of the credit.
Because there only were a limited number of palmito nurseries and the ones which existed only had small capacities *CARE* had to buy plants from the company *Agropalmito S.A.* in Guápiles and Rio Frio, both in the province Limon. These plants then were transported to the *CARE*-office in Upala. From thereon *CARE* distributed the plants among the farmers themselves. Normally the farmers would plant the palmito seedlings in the fields

immediately. But sometimes the seedlings weren't big enough to do that. In that case the seedlings had to be grown in communal *viveros* before planting in the fields. This was done by the farmers who received the plants. The plant nursery was established in the following way:
The *vivero* had to be made on a central spot in the community, for example near the meeting place of the *Asociación de Desarollo* or a school. The terrain must have a fence, to prevent chickens and horses to eat the young seedlings. When this terrain was ready, the seedlings were placed in the nursery. This was done in two ways. The first way took a long time. Seedlings were planted in black earth in black plant bags. The black earth was collected from the topsoil from nearby terrains. This "*enbolsar*" (putting seedlings in plant bags) was done by some participating farmers. Because of the long time necessary for this activity, only a small part of the plants was placed in the nursery this way. The rest was planted in the ground in the nursery directly. The plants in the bags were placed in rows. Seven rows were kept together between threads. Between these succeeding plantbeds of seven rows, paths were established.
From all the seedlings in the nursery the last (and this normally also is the biggest) produced leaf was cut away to prevent the plants from serious drying out. This because transpiration through a big leaf area exceeds water transport from the damaged (because of transplanting) roots to parts further into the plant. Another measure was to create shade over the seedlings. This was done with coconut leaves and bamboo stems.

These activities of transport, distribution and planting brought about the following problems:

- Transport of plants went hand in hand with damage to the plants. Many times stems were broken and roots were torn off.
- Transport costs were high because of the distance (approximately 5 houres by truck from Guápiles to Upala).
- Because the number of companies which could sell large numbers of seedlings was limited, sometimes too small seedlings were bought that couldn't be planted in the fields directly and thus had to be put into bags.
  Control over the quality depended thus also on the supply of yong palmito plants.
- Because of the nursery phase of plants that were too small to be planted in the fields directly, planting in the fields was strongly delayed, also because planting only is possible after the dry period.

- And the problem with the nursery phase is that the plants get one extra setback because of the extra planting.
- To grow plants in a nursery meant an extra task for the participating farmers that normally wouldn't have been necessary.

When the seedlings were planted in the fields, many times problems arose with overheating and drying out of the plants. This meant a growth delay. During visiting several farms, one farm was seen that solved this problem very good.
Before palmito seedlings were planted in the field, the farmer already grew maize with a large (2 meters) distance between the rows. When palmito plants had to be planted in the field, this maize already had a reasonable height. The palmito seedlings were planted between the maize rows. As could be seen easily, these palmito plants showed far less yellow and brown leaves. It was obvious that the provided shade from the maize worked very good for the palmito plants. And beyond that an extra maize harvest could be done.

While putting plants into bags, it became evident that young palmito stems were attracting many rats. Many plants that were waiting to be planted, were eaten just above ground level.
One farmer told that he had killed on one hectare of young palmito, approximately 70 rats the first day. The next day already he killed another 40!
An other animal that did many harm to young palmito plants was the *"taltuza"*. This animal eats the plant from under ground level. An among farmers widely spread method was used to kill the animal. Farmers put some poison on a peace of sugar cane stem and put it in the underground tunnelsystem. Because the animal would want to keep his tunnelsystem free or he would just like the food, he would eat away the stem and dy.
Plant losses because of rats and *taltuzas* vary strongly among fields and depend strongly on period of cultivation and type of previous cultivation. But losses can become really high.

Something very remarkable is that many farmers in the fields planted their plants during full moon phase or not far from that. They were convinced that plants performed better, because of a lower number of dead plants and a smaller transplant set-back ("transplanting shock").

To modern science this looks superstition because no or very little research has been done about this.

7.5 Reflections and recommendations on the *CARE*-project

The *CARE*-project functions very good. The clear set-up contributes for a great part to that. Tasks are divided clearly among the staff. In this project the project coordinator (ing. Ernesto Requeno Molina) can be regarded as the knowledge-source of this project. Especially his palmito-knowledge showed to be very important to the project. Formerly he had been working at the *Agropalmito Company* in Guápiles.
Weekly special meetings with the project coordinator and the extensionists were held. During these meetings, extensionists discussed problems which they had observed in the fields. Farmers themselves also pointed to their specific agricultural problems. The extensionists on their turn sought for solutions, and payed attention to these problems during the meetings. In cooperation with the project coordinator, subcoordinator (which was an agrono-mist) and all the extensionists solutions and/or suggestions were made. The extensionists on their turn provided the information to the farmers. On this way feed-back from the farmers was treated carefully.
Another indication for the projects success is the fact that the participation among the farmers was as was planned before. The desired area of palmito plants was likely to be reached.

The final objective of *PACCO*-projects in general was to raise family incomes in a sustainable way. The participants indeed obtained more control on their economic activities and their resources. This because better access was obtained to external resources (inputs as fertilizers, etc.). This better access also looks to be guaranteed for the future, because farmers are organised and can achieve things (for example buying of inputs at lower prices) communally. Because of this, farmers could control their crops and thus their economic activities better.
Productions on farmers fields probably also could be improved because of better access to inputs and advice of the extensio-nists.
But commercialization must be improved as well, otherwise the improved production would be of no importance. Because the farmers were organised better (committees), harvested products could be brought to the markets and sold communally. But the marketing of the palmito has to be organised. Because prices of unmanufactured palmitos were low, it was more profitable to sell palmitos in a form ready for consumption, than to sell palmitos to factories. It thus would improve commercialization very much when a manufacturing plant would be installed in the project

zone. But such a manufacturing plant has to be profitable itself too. And in the dry period in Upala production of palmito decreases, and the manufacturing plant would work far under its capacity. Unless of course palmito will be transported to the plant from other regions with a shorter dry period. The project coordinator mentioned a plan for installing a plant, but never concrete plans were heard. Nevertheless it remains a very crucial point that undoubtedly is of great importance for success or failure of the project.
Another necessity for realizing the final objective was to develop other economic resources as well. While visiting the fields not many activities for that were seen. Except some farmers which had installed plant nurseries with crops like palmito and black pepper.

The four components that had to result in the formerly mentioned effects were partly executed. Communal organization had been finished and should be working good. Although it is hard to believe that such elaborated organizations will work like they were expected to do.
Activities to incorporate women in the development proces as well, were not seen during the short fieldvisit period.
Development of small-scale economic activities wasn't seen neither, except for the plant nurseries again.
The establishment of the formation of a communal fund for credit depends on the degree of success of the communal organizations and the profitability of the agricultural activities.

When taking into account these outcomes of the objectives, it looks like this *PACCO*-project merely has a pure agricultural orientated strategy. A couple of important crops are introduced in a well-guided way by the project. And indeed these crops can fulfill the wish to provide higher incomes. But some crucial factors as the degree of success of communal organizations and the way of marketing (own manufacturing plant or not?) are very important to the degree of sustainability and thus success. When these factors are working out well, a successfull step is made in developing a Costa Rican region that formerly had been very underdeveloped and that was very poor.

Some recommendations can be made on basis of the formerly presented information.
To begin with it is a good step if the project could install some big palmitonurseries with the help of full-time workers. This provides extra income generation for some people. And very

important as well is the fact that transport costs can be limited and quality of the plants can be controled better. In the future these nurseries probably can continue because it is expected that because of the diffusion effect of the project more farmers will grow palmito in and outside the project zone. And still, plants could be sold to some companies etc.
Another important thing is the establishment of a manufacturing plant for palmito. To prevent too small supplies of palmito in the dry period it would be a good thing to attract supplies from regions (and even to contract palmito growers to sell their harvests to the manufacturing plant) during a minor dry period.
When the programme becomes a success it still (or especially then) is a good thing to promote other income generating activities. The zone then can count on a broader basis of income generation which is an important step in the development.

8 GENERAL CONCLUSIONS AND RECOMMENDATIONS

A general conclusion from this report can be drawn. As the results from the N-P-K fertilizer trial show, especially nitrogen (and to a lesser extent a combination of phosphate and potassium) fertilization leads to more vegetative growth (more suckers per plant, leaf area increases, etc.). Nitrogen fertilization increases yields. So proper fertilization is very important for farmers.

The description of the nutrient cycle according to Herrera (1989) led to the conclusion that the recommended N- and K-fertilization was respectively 8.9 and 4.3-5.4 times higher than the export (in yield). And these fertilizer recommendations still were very low compared to others (table 4.1).

What has to be studied, is a more sustainable way of fertilization. Yield optimalization (economical) and limiting nutrient losses to the environment should be strived for at the same moment.

Nutrient uptake efficiency has to be improved. Different fertilizer types and frequencies of using them, have to be researched. Also the role of the mulch layer with regard to fertilizer efficiency has to be investigated. These mulch layer can play an important role in nutrient fixing and releasing. Even some studies showed that palmito can live together with mycorrhizae, which can release phosphate even in very acid soils. Further research on this subject seems worthwile.

This more sustainable fertilization strategy should lead to lower fertilizer uses. This especially is important for smallholders who cultivate palmito. For them it is of major importance to minimize costs of production, because costs and benefits only are separated by a narrow space.

9 PERSONAL EXPERIENCE

When you study a tropical orientation, it is obliged to do a practical period there. It is even adviced to do your thesis abroad too. My choice for Costa Rica to fulfill my practical period was more or less a jump in the dark. Of course I already heard a lot of stories, but how I would experience the new atmosphere, people, language, etc., still was a question.
A language course at the CLM (Centro Linguistico Maya) in Antigua (Guatemala) improved my knowledge of the Spanish language a lot. And the social contacts in Guápiles (CR) really helped me to be able to speak a reasonable mouth full of Spanish.
The life on the project in Guápiles was very easy. Not really the type you would expect in a development country. The big Dutch community even created a bigger difference between real Costa Rican life and that of mine. Despite all this I would say that for a student who just is having his first tropical experience -life and work on a project like this- it is a very good start. During my work I always received a lot of support from either the Costa Rican staff as well from my supervisor. For some topics I even could go to fellow students. Computers on the project nearly always were in use by students, but despite this analysing of data was not a problem.
Some things were very valuable for me to learn. While working and looking around to all the agricultural aspects in CR, I came to realize which direction I wanted to give my study at the university in Wageningen. Research on farming systems/cropping systems is very interesting to me.
Another very important experience was the practical period I fulfilled in Upala at the CARE-project. While being among Costa Ricans themselves, one comes to realize how different our ways of life are. For me, positive feelings dominate very much over the negative ones. I really had a very cheerful time.
I still have to practice my thesis somewhere, but I think that this first experience always leaves behind the largest impression. "Costa Rica, Guatemala, I will be back some day!"

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APPENDICES

Appendix 6-I. Lay-out of the N-P-K fertilizer trial for palmito

Code: NPK H

N = quantity of nitrogen: 0, 1 or 2 times 372 $kg \cdot ha^{-1} \cdot y^{-1}$
P = quantity of phosphor: 0, 1 or 2 times 408 $kg \cdot ha^{-1} \cdot y^{-1}$
K = quantity of potassium: 0 or 1 x 360 $kg \cdot ha^{-1} \cdot y^{-1}$
H = harvest number 1 to 4 (1st harvest was realized)

121 2	020 1	121 4	110 3	101 1	021 3	010 1	001 3	120 4	Replicate
011 3	100 1	201 4	211 3	000 4	220 3	200 1	221 2	120 3	I
210 4	201 1	100 2	110 4	000 3	000 1	001 2	010 4	111 3	
201 3	201 2	020 2	101 2	000 2	101 3	221 4	001 1	111 1	
100 4	100 3	011 4	110 1	220 1	220 4	010 3	111 4	200 2	
121 3	210 1	020 3	220 2	211 4	110 2	111 2	200 3	120 1	
121 1	011 1	011 2	211 1	021 1	021 4	221 3	200 4	221 1	
210 3	020 4	210 2	021 2	101 4	211 2	020 2	001 4	120 2	
110 4	220 1	201 2	020 2	111 3	111 4	101 4	211 3	120 3	Replicate
011 2	121 4	110 3	111 2	100 3	210 4	211 1	010 3	120 1	II
110 2	000 1	220 3	111 1	001 2	001 3	021 3	211 2	021 4	
000 4	000 2	011 1	020 1	100 2	221 2	200 3	021 2	101 3	
201 3	220 4	121 1	100 4	221 1	221 3	101 1	120 2	211 4	
121 2	201 1	000 3	221 4	210 1	210 3	200 4	101 2	021 1	
011 3	110 1	201 4	020 4	020 3	001 1	010 1	010 4	010 2	
011 4	121 3	220 2	210 2	001 4	100 1	200 1	200 2	120 4	
000 4	210 2	221 1	111 1	010 4	010 3	020 2	200 2	211 4	Replicate
120 3	210 3	101 3	111 3	201 1	220 4	110 2	211 1	020 4	III
000 2	210 1	000 1	100 3	021 4	021 2	121 2	121 1	020 3	
221 3	011 3	011 2	100 2	111 2	220 3	200 3	110 4	001 2	
101 4	120 2	011 4	100 1	220 2	021 1	001 3	001 4	020 1	
011 1	221 2	210 4	111 4	201 3	010 1	121 4	001 1	110 3	
101 1	000 3	120 4	100 4	220 1	021 3	211 2	200 1	211 3	
221 4	101 2	120 1	201 4	201 2	010 2	110 1	121 3	200 4	
000 2	021 2	120 4	010 3	211 4	121 3	221 3	110 1	011 4	Replicate
111 3	210 2	111 1	001 3	211 2	220 1	020 3	200 4	020 4	IV
201 3	021 4	021 1	121 4	001 2	010 4	200 1	221 4	200 2	
210 3	120 2	111 4	220 3	211 1	100 4	101 3	110 2	011 2	
210 1	201 4	000 3	220 4	121 1	121 2	110 4	020 2	011 3	
111 2	120 3	000 1	001 4	100 1	220 2	101 2	011 1	221 1	
210 4	201 1	201 2	001 1	100 3	010 2	200 3	221 2	020 1	
000 4	120 1	021 3	010 1	211 3	100 2	101 4	110 3	101 1	

N

Appendix 6-II. Weather data of meteorological station Los Diamantes

March 1993

daynumber	Tmin	Tmax	Tmean	Tsum	prec
1	16,5	29,7	23,1	23,1	0,0
2	15,5	30,3	22,9	46,0	0,0
3	16,4	29,9	23,2	69,2	0,0
4	16,0	29,9	23,0	92,1	0,0
5	17,0	30,0	23,5	115,6	0,0
6	16,5	30,2	23,4	139,0	0,0
7	17,5	29,8	23,7	162,6	0,0
8	17,5	28,8	23,2	185,8	1,0
9	18,0	30,0	24,0	209,8	0,0
10	17,2	30,2	23,7	233,5	0,0
11	20,8	30,2	25,5	259,0	0,7
12	22,2	28,9	25,6	284,5	0,4
13	21,3	30,8	26,1	310,6	101,0
14	18,0	25,8	21,9	332,5	39,5
15	19,0	21,9	20,5	352,9	25,1
16	21,5	27,6	24,6	377,5	18,5
17	21,4	25,0	23,2	400,7	2,1
18	17,5	31,1	24,3	425,0	0,0
19	19,0	25,9	22,5	447,4	29,7
20	21,0	24,4	22,7	470,1	84,6
21	21,0	27,4	24,2	494,3	4,5
22	17,8	29,5	23,7	518,0	0,0
23	20,5	26,7	23,6	541,6	10,8
24	20,5	27,0	23,8	565,3	7,2
25	20,0	30,2	25,1	590,4	0,0
26	18,0	29,0	23,5	613,9	0,8
27	21,5	30,2	25,9	639,8	0,0
28	21,0	29,0	25,0	664,8	86,1
29	21,2	28,9	25,1	689,8	19,9
30	20,7	29,0	24,9	714,6	11,3
31	20,5	29,5	25,0	739,6	0,0
sum	592,5	886,8	739,6	739,6	443,2
mean	19,1	28,6	23,9		14,3

April 1993

daynumber	Tmin	Tmax	Tmean	Tsum	prec
1	21,5	30,6	26,1	26,1	0,0
2	19,6	30,0	24,8	50,9	1,0
3	22,5	27,9	25,2	76,1	7,5
4	21,5	29,5	25,5	101,6	0,0
5	21,2	26,8	24,0	125,6	4,8
6	21,8	29,5	25,7	151,2	0,0
7	20,0	29,2	24,6	175,8	6,5
8	20,8	27,4	24,1	199,9	0,1
9	20,0	31,5	25,8	225,7	0,0
10	20,5	31,0	25,8	251,4	0,0
11	21,2	30,9	26,1	277,5	1,0
12	21,0	30,0	25,5	303,0	7,1
13	22,5	30,2	26,4	329,3	0,0
14	19,5	31,3	25,4	354,7	1,9
15	20,2	32,0	26,1	380,8	0,0
16	20,8	32,4	26,6	407,4	0,0
17	20,2	32,3	26,3	433,7	0,0
18	20,5	32,2	26,4	460,0	0,0
19	21,5	31,4	26,5	486,5	1,0
20	22,0	31,0	26,5	513,0	0,0
21	20,0	31,8	25,9	538,9	0,0
22	20,0	31,6	25,8	564,7	58,8
23	21,0	25,8	23,4	588,1	48,2
24	20,2	29,7	25,0	613,0	0,0
25	21,4	30,5	26,0	639,0	50,9
26	21,5	30,0	25,8	664,7	0,0
27	19,3	29,2	24,3	689,0	0,0
28	19,4	30,9	25,2	714,1	1,0
29	20,5	30,4	25,5	739,6	13,9
30	19,8	29,0	24,4	764,0	0,5
31					
sum	621,9	906,0	764,0	764,0	204,2
mean	20,7	30,2	25,5		6,8

May 1993

daynumber	Tmin	Tmax	Tmean	Tsum	prec
1	20,6	28,2	24,4	24,4	3,7
2	21,0	30,6	25,8	50,2	0,0
3	20,5	31,4	26,0	76,2	3,0
4	21,2	30,9	26,1	102,2	0,0
5	22,0	30,2	26,1	128,3	0,0
6	20,2	31,5	25,9	154,2	0,0
7	19,5	31,6	25,6	179,7	0,0
8	21,7	31,0	26,4	206,1	1,0
9	22,0	32,2	27,1	233,2	61,6
10	21,0	31,3	26,2	259,3	56,2
11	21,5	30,7	26,1	285,4	26,0
12	22,9	31,4	27,2	312,6	35,2
13	22,0	30,4	26,2	338,8	2,2
14	21,0	30,5	25,8	364,5	0,0
15	21,2	30,7	26,0	390,5	44,6
16	22,8	29,9	26,4	416,8	3,0
17	21,5	31,4	26,5	443,3	1,4
18	22,7	31,5	27,1	470,4	16,6
19	20,5	31,0	25,8	496,1	6,9
20	20,7	31,3	26,0	522,1	26,2
21	22,2	30,2	26,2	548,3	0,0
22	22,0	30,9	26,5	574,8	39,9
23	22,0	31,2	26,6	601,4	4,9
24	21,2	31,4	26,3	627,7	66,3
25	21,5	30,4	26,0	653,6	16,3
26	22,4	28,4	25,4	679,0	6,3
27	20,7	29,0	24,9	703,9	15,9
28	21,7	29,9	25,8	729,7	1,8
29	21,6	28,5	25,1	754,7	26,7
30	20,5	30,7	25,6	780,3	9,0
31	22,0	29,5	25,8	806,1	31,7
sum	664,3	947,8	806,1	806,1	506,4
mean	21,4	30,6	26,0		16,3

June 1993

daynumber	Tmin	Tmax	Tmean	Tsum	prec
1	21,8	33,3	27,6	27,6	23,8
2	21,5	32,2	26,9	54,4	0,3
3	22,5	29,5	26,0	80,4	13,2
4	21,6	30,9	26,3	106,7	0,0
5	23,0	29,0	26,0	132,7	20,9
6	21,5	29,9	25,7	158,4	0,0
7	22,0	25,5	23,8	182,1	40,8
8	19,5	30,4	25,0	207,1	0,5
9	21,6	29,5	25,6	232,6	2,9
10	22,0	30,6	26,3	258,9	28,8
11	21,5	28,3	24,9	283,8	28,2
12	21,8	27,3	24,6	308,4	79,5
13	22,8	28,8	25,8	334,1	22,6
14	20,6	30,0	25,3	359,4	1,3
15	22,8	30,5	26,7	386,1	0,0
16	22,0	31,0	26,5	412,6	0,0
17	21,0	31,5	26,3	438,9	0,0
18	21,9	30,5	26,2	465,1	1,3
19	21,5	28,0	24,8	489,8	0,0
20	21,3	29,0	25,2	515,0	0,1
21	22,3	28,3	25,3	540,3	8,7
22	21,1	28,9	25,0	565,3	2,8
23	22,0	29,0	25,5	590,8	46,7
24	20,0	30,5	25,3	616,0	21,9
25	20,6	30,5	25,6	641,5	43,4
26	22,2	28,2	25,2	666,8	0,0
27	21,4	28,9	25,2	691,9	6,3
28	21,2	28,6	24,9	716,8	40,2
29	20,5	29,1	24,8	741,6	20,8
30	23,2				
31					
sum	648,7				
mean	21,6				

explanation:

daynumber	date
Tmin	minimum temperature (nighttemp.)(degr. celsius)
Tmax	maximum temperature (daytemp.)(degr. celsius)
Tmean	mean temperature ((Tmin+Tmax)/2)
Tsum	accumulated temperature (degr. celsius), beginning in day 1
prec	precipation (mm)

Appendix 6-III. Form for data collection of plant measurements

Repetición	R1	Tratamiento	N-PK = 00

Clases (cm)		0 - 25	25 - 50	50 - 75	> 75
hijos	altitud (cm)	21	49	65	94
	ancho (cm) (omtrek)	3,8	15,7	13,2	30,2
	peso fresco total (g)	53,06	825	1225	3975
Tallo	peso fresco total (g)	28,89	567,63	768,72	2860
Area foliar	peso fresco total de las hojas (g)	24,17	257,53	456,28	1115
	A.F. estimado con fórmula				
	A.F. medido con máquina				
Sub-muestra hojas	peso fresco (g)				
	A.F. medido con máquina				
	peso seco (g)				

Tallo	submuestra de los cuatro hijos juntos	peso fresco (g)	500,16
		peso seco (g)	74,57

Appendix 6-IV. Results of the statistical analysis of data on plant characteristics

Table 6.1a Results of the stepwise multiple regression analysis. Dependent variables, independent variables, (partial) regression coefficients (B), standard errors of the regression coefficients (Se B), F-values of the independent variables, significant F values (sig F) and correlation coefficient between the dependent variable and the independent variable(s) (Mult. R_{model}).

Dependent variable	Independent variable(s)	B *	Se B	F-value	sig F	Mult. R_{model}
Total number of suckers per plant	N-level	1.69	0.65	6.84	0.01	0.41
	PK-level	1.50	0.64	5.46	0.02	
	(constant)	6.29	0.54	137.00	0.00	
Total number of formed leaves per sucker	Replicate	0.18	0.09	4.08	0.04	0.10
	(constant)	5.68	0.24	571.105	0.00	
Number of dead leaves per sucker	N-level*PK-level	0.25	0.10	5.59	0.02	0.15
	Replicate	-0.09	0.04	4.54	0.03	
	(constant)	0.75	0.11	47.56	0.00	
Actually present leaf area per sucker (cm^2)	N-level	8406.77	2590.55	10.53	0.00	0.29
	(constant)	9669.49	1954.05	24.49	0.00	
Total leaf area per sucker (cm^2)	N-level	9148.62	2732.36	11.21	0.00	0.30
	(constant)	9926.42	2054.21	23.35	0.00	
Leaf area of second-last leaf per sucker (cm^2)	N-level	3826.43	968.90	15.60	0.00	0.35
	(constant)	3727.78	726.68	26.32	0.00	
Leaf area of last leaf per sucker (cm^2)	N-level	4166.21	1186.80	12.32	0.00	0.33
	(constant)	4933.81	875.09	31.787	0.00	
leaf formation time	No significant difference					
Height last leaf sheath per sucker (cm^2)	N-level	10.42	2.72	14.67	0.00	0.18
	(constant)	48.37	1.88	660.93	0.00	
Number of harvested suckers per field of four plants assumming a linear relation	N-level ($kg*ha^{-1}*y^{-1}$)	$43*10^{-4}$	$96*10^{-5}$	20.73	0.00	0.48
	(constant)	2.26	0.41	30.39	0.00	

* Meaning of N-levels: 0=0 kg $N*ha^{-1}*y^{-1}$
1=672 kg $N*ha^{1}*y^{-1}$
PK-levels: 0=0 kg $P*ha^{-1}*y^{-1}$, 0 kg $K*ha^{-1}*y^{-1}$
1=816 kg $P*ha^{-1}*y^{-1}$, 360 kg $K*ha^{-1}*y^{-1}$

Table 6.1b Table 6.1 continued. Number of harvested suckers per field of four plants, assuming a <u>non-linear</u> relation with fertilization.

Dependent variable	Independent variable(s)	B	Se B	F-value	sig F	Mult. R_{model}
Number of harvested suckers per field of four plants (N-level= 0 and 336 $kg*ha^{-1}*y^{-1}$)	N-level ($kg*ha^{-1}*y^{-1}$)	$63*10^{-4}$	$18*10^{-4}$	11.97	0.00	0.45
	(constant)	2.04	0.43	22.09	0.00	
Number of harvested suckers per field of four plants (N-level= 336 and 672 $kg*ha^{-1}*y^{-1}$)	No significant difference					

Table 6.1c Table 6.1 continued.

Dependent variable	Independent variable(s)	B *	Se B	F-value	sig F	Mult. R_{model}
Mean number of suckers per plant	Replicate*N-level *PK-level	0.89	0.28	10.40	0.00	0.67
	(constant)	7.41	0.38	372.98	0.00	
Mean number of formed leaves per sucker	Replicate	0.25	0.05	22.64	0.00	0.80
	(constant)	5.57	0.15	1431.30	0.00	
Mean number of dead leaves per sucker	No significant difference					
Mean actually present leaf area per sucker (cm^2)	N-level	9656.2 2	3118.7 2	9.59	0.01	0.65
	(constant)	8772.6 2	2130.4 9	16.96	0.00	
Mean total leaf area per sucker (cm^2)	N-level	10160. 8	3400.6 1	8.93	0.01	0.64
	(constant)	8945.7 6	2323.0 6	14.83	0.00	
Mean leaf area of second-last leaf per sucker (cm^2)	N-level	4109.0 5	1263.9 2	10.57	0.01	0.67
	(constant)	3519.6 9	863.42	16.62	0.00	
Mean leaf area of last leaf per sucker (cm^2)	N-level	4188.7 6	1695.3 3	6.11	0.03	0.57
	(constant)	4761.7 9	1158.1 3	16.91	0.00	
Mean height last leaf sheath per sucker (cm^2)	N-level	11.60	3.32	12.18	0.00	0.70
	(constant)	47.86	2.27	444.59	0.00	

* Meaning of N-levels: 0=0 kg $N*ha^{-1}*y^{-1}$
1=672 kg $N*ha^{1}*y^{-1}$

PK-levels: 0=0 kg $P*ha^{-1}*y^{-1}$, 0 kg $K*ha^{-1}*y^{-1}$
1=816 kg $P*ha^{-1}*y^{-1}$, 360 kg $K*ha^{-1}*y^{-1}$

Table 6.2 Results of the analysis of variance. Dependent variables, independent variables, sum of squares, degrees of freedom, mean squares, F-values and significant F-values

Dependent variable	Independent variables	Sum of squares	DF	Mean square	F-value	Sig F
Growth rate of height last leaf sheath between measuring period 1 and 2	Replicat*N-level	1.079	3	0.360	5.111	0.00
Growth rate of height last leaf sheath between measuring period 2 and 3	Replicat*N-level*PK-level	0.682	2	0.341	7.647	0.00
Development rate of total formed leaves between measuring period 1 and 2	Replicat	0.005	3	0.002	11.487	0.00
Development rate of total formed leaves between measuring period 2 and 3	Replicat	0.001	3	0.000	2.743	0.043

Table 6.3 Results of the stepwise multiple regression analysis. Dependent variables, independent variables, (partial) regression coefficients (B), standard errors of the regression coefficients (Se B), F-values of the independent variables, significant F values (sig F) and correlation coefficient between the dependent variable and the independent variable(s) (Mult. R_{model}).

Dependent variable	Independent variable(s)	B *	Se B	F-value	sig F	Mult. R_{model}
Specific leaf area (cm^2/g)	Class	-18.76	5.91	10.05	0.00	0.45
	(constant)	243.12	16.70	211.82	0.00	
Leaves (d.m.) as percentage of total plant (above ground part)	Class	-3.31	1.25	6.99	0.01	0.39
	(constant)	53.22	3.56	222.92	0.00	
Stem (d.m) as percentage of total plant (above ground part)	Class	3.31	1.25	6.99	0.01	0.39
	(constant)	46.78	3.56	172.24	0.00	
Percentage dry matter of leaves	Class	3.25	0.65	24.62	0.00	0.60
	(constant)	22.46	1.88	143.35	0.00	
Percentage dry matter of stem	No significant difference					

* Meaning of length class levels: 1 = 0 - 25 cm
2 = 25 - 50 cm
3 = 50 - 75 cm
4 =75 - >75 cm