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MULCHING IN PALM HEART

A study on the effects of mulching in a Palm heart plantation in the Atlantic Zone of Costa Rica

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CENTRO AGRONOMICO TROPICAL DE INVESTIGACION Y ENSEÑANZA (CATIE)

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REPOSA (*Research Program on Sustainability in Agriculture*, o sea Programa de Investigación sobre la Sostenibilidad en la Agricultura) es una cooperación entre la Universidad Agrícola de Wageningen, Holanda (UAW), el Centro Agronómico Trópical de Investigación y Enseñanza (CATIE) y el Ministerio de Agricultura y Ganadería de Costa Rica (MAG). Además REPOSA ha firmado cartas de entendimiento con organizaciones académicas, gubernamentales, internacionales y non-gubernamentales en Costa Rica.

REPOSA ha desarrollado una metodología cuantitativa para el análisis del uso sostenible de la tierra para apoyar la toma de decisiones a nivel regional. Esta metodología, llamada USTED (Uso Sostenible de Tierras En el Desarollo) involucra dimensiones económicas y ecológicas, incluyendo aspectos edafológicos y agronómicos.

REPOSA ofrece facilidades para investigaciones y enseñanza para estudiantes tanto de la UAW, como de otras institutiones educacionales holandesas y regionales.

REPOSA publica sus resultados en revistas científicas, tesis de grado, informes, y ponencias en conferencias y talleres. REPOSA regularmente organiza demostraciones para investigadores de Costa Rica y de otros países para familiarizarlos con la metodología USTED.

REPOSA es financiado por la UAW bajo su Programa del Uso Sostenible de la Tierra en los Areas Trópicos. La sede de REPOSA está ubicada en la Estación Experimental Los Diamantes del MAG en Guápiles.

The Research Program on Sustainability in Agriculture (REPOSA) is a cooperation between Wageningen Agricultural University (WAU), the Center for Research and Education in Tropical Agriculture (CATIE), and the Costa Rican Ministry of Agriculture and Livestock (MAG). In addition, REPOSA has signed memoranda of understanding with numerous academic, governmental, international, and non-governmental organizations in Costa Rica.
The overall objective of REPOSA is the development of an interdisciplinary methodology for land use evaluation at various levels of aggregation. The methodology, based on a modular approach to the integration of different models and data bases, is denominated USTED (*Uso Sostenible de Tierras En el Desarrollo*; Sustainable Land Use in Development).
REPOSA provides research and practical training facilities for students from WAU as well as from other Dutch and regional educational institutions.
REPOSA's research results are actively disseminated through scientific publications, internal reports, students' thesis, and presentations at national and international conferences and symposia. Demonstrations are conducted regularly to familiarize interested researchers and organizations from both within and outside Costa Rica with the *USTED* methodology.
REPOSA is financed entirely by WAU under its Sustainable Land Use in the Tropics program, sub-program Sustainable Land Use in Central America. It operates mainly out of Guápiles where it is located on the experimental station *Los Diamantes* of MAG.

PREFACE

This report presents a description and analysis of a mulch experiment within a palm heart plantation of Agropalmito near Guápiles, Costa Rica. The experiment was started in May 1993 and has been continued until now. This report contains the results of the field and laboratory work done until 1995.

The work was supervised by Ir. Donatus Jansen in Costa Rica and Ir. Theo Guiking of the department of Tropical Crop Science of the Wageningen Agriculture University. I would like to thank my supervisors for their help and comments and I would like to give a special thank to Don Migael, Enrique and Werner for their help, their jokes and their kindness.

SUMMARY

In the Atlantic Zone programme in Guápiles, Costa Rica a research is done on land use and land use planning. One of the crops of this Atlantic Zone is Palm heart (Bactris gasipaes H.B.K.). This palm tree is grown since ancient times for its fruits in Tropical America. When the palms are young they can be harvested for the palm heart ('palmito'), which is the content of the psuedostem. Although palm heart is commercially grown for more than 20 years, it still is seen as a future crop with its expanding reputation and export market.

In a palm heart plantation a mulch experiment is set up to investigate the effect of mulch on soil (micro and meso) fauna and flora leading to improved soil properties and hence crop performance. Mulching is covering the soil with some organic materials, in this case crop residues (sheets and leaves). Two fields within the plantation were selected, differing in soil type and age of establishment. In each field a 3 by 3 factorial experiment (no - normal - double mulch, and no - half of normal - normal N fertilization) is laid out with four replicates per field. Daily management of the experiment started in May 1993 and continued until now. Besides normal management the crop residues have to be weighted and transported directly after harvesting and a sample of the residues has to be taken for N, P, K analyses.

It was postulated that in the humid tropics under a perennial self mulching crop no effect of mulch can be expected due to better infiltration of rainwater, reduction of evaporation, reduction of soil temperature, or import of nutrients.

The hypothesis is that mulching improves the soil flora and fauna leading o.a. to a better soil structure. However this effect cannot be determined directly without destroying the soil and the experiment. Effects resulting from a better structure (improved soil properties and crop performance) could be determined in soil water conditions by analyzing the soil suction on different depths and distances from the palm, palm heart production, by analyzing the harvest data and nutrient content of the harvest residues.

The result showed that after one year of managing the experiment no effects can be recognized in total yield of palm heart. A relation between mulch production and nutrient uptake could not be distinguished. The mulch has some effect on the soil suction characteristics, but how much and how related is not worked out. The whole experiment considered, more time and data are needed to be able to distinguish any effects of the different mulch and N treatments.

CONTENTS

1 INTRODUCTION

Within the study Environmental Science of the Wageningen Agriculture University there exists the possibility to do a practical. I was interested to do a study on a subject that was a combination of agronomy and soil science, with regard to sustainable agriculture. I found an investigation of the department of Agronomy set out in a palm heart plantation in the lowlands of Costa Rica. Palm heart is the product of the young peach palm (Bactris gasipaes H.B.K.). Although commercially grown for more than 20 years, it still is seen as a future crop with its expanding reputation and export market. In the palm heart plantation a mulch experiment was set up to investigate the effect of mulch on soil (micro and meso) fauna and flora leading to improved soil properties and hence crop performance. Mulching can have different effects depending of the climatic, crop and soil conditions. The main positive effect of mulching in the humid tropics is the build up and maintenance of a flourishing soil (micro) fauna and flora. This is the main hypotheses for the design of the mulch experiment. My task was to continue the experiment and to collect data and analyze them. I had to plan the activities, organize people and work with them in the field.

The investigation is part of the Atlantic Zone Program, a joined project of Wageningen Agricultural University, Ministry of agriculture (MAG) and Centre for Research and Education in Tropical Agriculture (CATIE).

This report first describes the Atlantic Zone of Costa Rica (Chapter 1), then the Atlantic Zone Program (Chapter 2). Next some information is given of palm heart cultivation (in the Atlantic Zone of Costa Rica) in Chapter 4. In Chapter 5 the mulch experiment is described and results are worked out. In Chapter 6 I will tell about my own experiences in Costa Rica.

The Atlantic Zone is the popular name for the research-area of the Atlantic Zone Program. This area was arbitrary defined as the northern part of the province of Limon, the canton Sarapíqui of Heredia. It is situated in the eastern part of Costa Rica between 10° and 11° northern latitude and 83° and 84° western longitude (figure 2.1), and comprises an area of circa 11,000 km². It is bordered by the volcanic ranges of the Turrialba (3329 m) and Irazu (3423 m) in the west and the Atlantic ocean in the east. During the second phase of the Program the USTED methodology (see Chapter 3) has been developed and applied at the sub-regional level for the Negev settlement located in the northern part of Limon province of Costa Rica.

In many reports produced within the AZP, extensive information can be found on subjects like climate, soils, vegetation and land use. Therefore here only a short description of these topics is given.

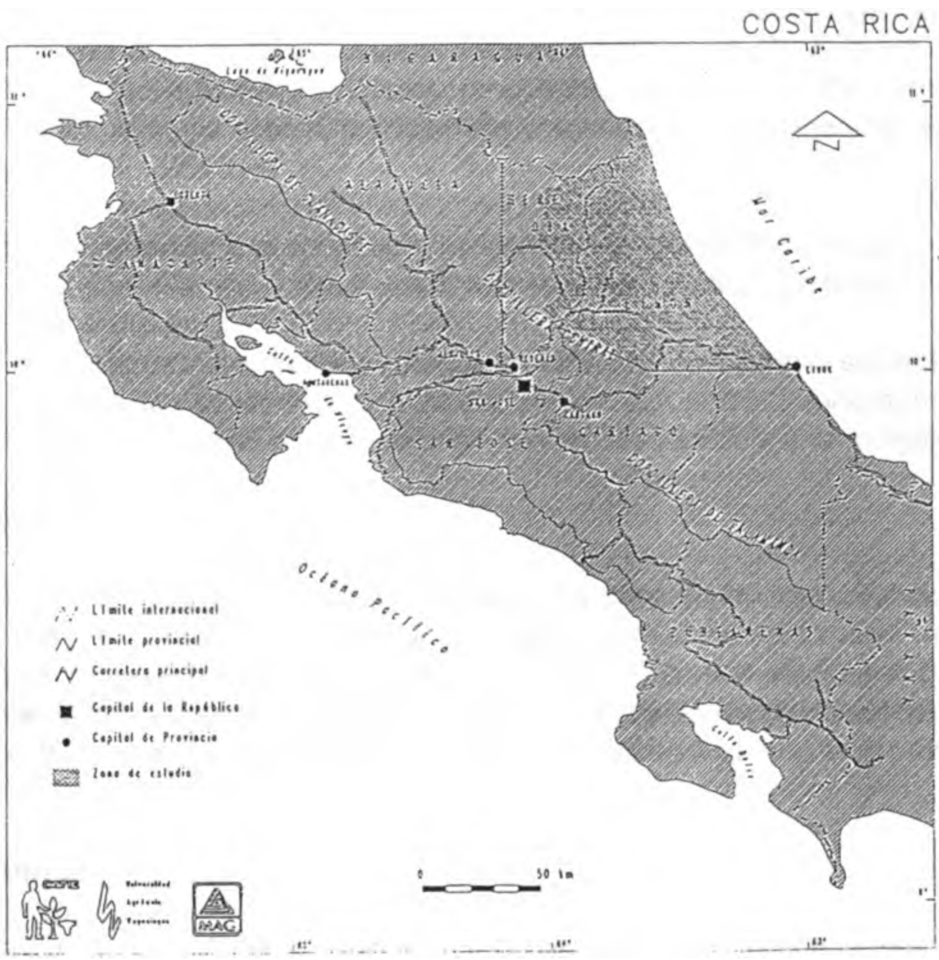

Figure 2.1 Location of the Atlantic Zone within Costa Rica.

2.1 Climate

In the Atlantic Zone the climate is characterized as tropical humid (Jongschaap, 1993). Small temperature changes throughout the year occur. Annual variation of temperature is dominated by the monsoon with the highest temperatures before the onset of the summer-rains, which start around July (Portig, 1976). Total rain amounts from 2500 mm per year to 4500 mm per year in the northeast and east of the zone, respectively. Mean annual temperature varies from 18° to 24° C , mainly depending on altitude. Potential evapo-transpiration in the Atlantic Zone varies between 3 mm per day in June and 4.2 mm per day in March and April. This climate enables crop growth throughout the year (Jongschaap, 1993).

2.2 Soils

The Atlantic Caribbean lowland has been a sedimentation area since early Tertiary. The coastline is made up by a narrow strip of succeeding beach ridges with parallel canals. Inland of these canals coastal swamps occur, gradually passing into a vast alluvial plain. At the foot of the volcano ranges the alluvium takes the form of alluvial fan deposits. At some places, the flat plain landscape is interrupted by remnants of basaltic tertiary volcanoes.

Roughly the following groups of soils can be distinguished (Stoorvogel et al., 1995);

1) young alluvial well drained volcanic soils with a relative high fertility (inceptisols and andisols),
2) relatively old well drained soils developed on fluvio-laharic sediments with a relatively low soil fertility (oxisols and inceptisols) and 3) young poorly drained volcanic soils with a relatively high soil fertility (entisols and inceptisols).

2.3 Vegetation

About hundred years ago, most of the area was covered by tropical moist and wet forest and pre-montana wet forest. On the higher parts of the central and Talamancan mountain ranges, situated in the south of the Atlantic Zone Area lower-montane and montane rain-forest were found. At present much of the forest has been destroyed for wood extraction and because of conversion into pasture and crop land (Jongschaap, 1993).

2.4 Land use

The land use in the Atlantic Zone is very variable in time and space (see figure 2.2) with regards to crops, management and field size. The Atlantic Zone has a humid tropical climate with a rainfall surplus over evapo-transpiration in most months of the year and large areas of fertile soils of recent volcanic origin situated in a rather flat alluvial plain. These conditions enable the production of a large variety of crops. Farms produce cassava, plantain and pineapple and also vegetables (sweet peppers and chili), citrus fruits and other roots (yam and chamol). Maize was an important crop in earlier days, but presently it is cultivated only for own use.

Plantations cultivate in general bananas, palm heart and ornamental plants. The greater part produced for export. In addition, pastoral systems for beef production are found, some with silvo-pastoral systems and forestry for timber. A considerable area is set aside as national park of forest reserve in which eco-tourism is being developed (Alfaro et al., 1994)

Land use is influenced by many factors. Land use is related to soil fertility and drainage. Most plantations are found on the fertile soils, naturally well drained, or drained by canals. Sections of the badly drained soils are not appropriate for other land use than forest, if no drainage system is made. Most crops are restricted to the fertile, well drained soils, although also some crops are found on the infertile soils (e.g. pineapple and palm heart). Pasture is found on all soil types. Banana plantations often have sufficient capital to get access to the more fertile soils or to construct a good drainage system (Belder, 1994).

Farm size is an other factor that influences land use. Banana is generally found on big plantations. For small farmers the cultivation of arable crops is generally the most important activity. This is the case, among others, in the settlements of the Instituto de Desarollo Agricola (IDA, the Institute for Agricultural Development), which buys large farms and redistributes it in parcels between 5 and 10 ha. More annual crops can be found in than outside the settlements (Belder, 1994).

A relation between land use and infrastructure is present. The general trend is that with increasing road density field sizes decrease and the land use is more intensive (Belder, 1994). An other factor that influence land use is formed by prices of input and output. Before 1988, the cultivation of maize was promoted by a governmental subsidy on grain maize. After the abolition of this subsidy, maize is almost only cultivated for own consumption and occupies only limited areas of land. The land use in protected areas is mostly primary forest, but colonization takes place.

3 THE ATLANTIC ZONE PROGRAM

To determine and investigate the local land use conditions in the Atlantic Zone of Costa Rica, the Atlantic Zone Program (AZP) was established in 1986 as a joint project between Costa Rican Ministry of Agriculture (MAG, Ministerio de Agricultura y Ganaderia), the Centre for Research and Education in Tropical Agriculture (CATIE, Centro Agronómico Tropical de Investigación y Enseñanza) and the Agricultural University Wageningen (AUW, the Netherlands). The agreement offered the AUW opportunities for research and training of students and CATIE and MAG access to the information and experience of the WAU in the region.

The program started in April 1986 with a diagnosis of the agricultural problems in the zone. Later on possible research projects were determined. During phase one ('86-'90) multi- disciplinary research was started, aimed at rational use of the natural resources in the Atlantic Zone with emphasis on the small landowner. In 1991 an evaluation of the project was carried out. The continuation of the project was secured by provisional finance for 3 years after a new research program had been developed, in relation to the AUW policy of linking funding of outreach station (steunpunt) projects to results of investigations.

The research plan of the second phase has since 1991 focused on the development and testing of a methodology for analysis and planning of sustainable land use, both in ecological and economical terms. For pragmatic reasons the study area was limited to the northern part of the Limón province (Oostrom, 1993).

The methodology developed in the second phase named "Uso Sostenible para Tierras En el Desarollo" (USTED: Sustainable land use in development). The methodology incorporates a linear programming model, a geographic information system, and a customized data management tool. The options for land use are described at field level, but the methodology allows analyses for land use at the field, the farm and the regional level (Jansen et al., 1995)

In this methodology a farm is considered to comprise one or more land units (LUs), the natural resources. These are defined by their soil types with a number of pedological characteristics and slope. Technical options for the use of each LU are given by Land Use Systems with a specified Technology (LUSTs). A LUST is a combination of Land Unit (LU), land utilization type (LUT) and technology. The core is formed by a chronological description of a particular operation sequence, such as sowing, fertilizing, harvesting, in which all field operations are quantified in use of labour, traction, equipment and materials. Thereby permitting desorption of different technologies by varying the use of input and the resulting output. The LUSTs descriptions quantify all inputs and outputs, but do not contain all the information needed to calculate the coefficients for use in the optimization model. This information, called attributes, contains prices, nutrient contents, toxicity etc. and is stored separately from the LUSTs (Jansen and Schipper, 1995).

The ecological sustainability of the land use system is evaluated on the basis of two criteria: the nutrient balance and the use of agro-chemicals. Since the aim of the study is to indicate possible land use under changing conditions, not only the actually occurring LUSTs are described, but alternatives are identified as well.

The mulch experiment described in Chapter 5 allows a better quantification of the nutrient balance used in USTED. It can give some interesting information about nutrient uptake, recycling of nutrients released by the decomposition of the crop residues.

Description of actual occurring LUSTs are based on research on farm level and on LUT level (Jongschaap, 1993 ; Tõnjes, 1994). Alternative LUSTs are constructed with the use of literature data, fertilizer experiments (Chin, 1994) and expert knowledge (a.o. a crop simulation model of maize; a crop growth simulation model for peach palm is in development). In the optimization model, various farm-types have been distinguished, differing in size and soils. To each of these farm types all the LUSTs are offered in the optimization model, to calculate optimal land use in relation to the goal and the constraints (a.o. labour availability, limits to N, P, and K supply). For each LU only a few LUST can be projected, due to the limits of calculation of the model.
At the end of the second phase the USTED methodology is functional on the sub-regional level, with the Neguev settlement as example (Schipper, 1994).

In 1994 the third phase of the project started. In this phase the methodology developed for the Atlantic Zone will be extended to incorporate the regional level and to improve the animal production system. The methodology will be tested in another area of Costa Rica (Guanacaste), with different climate, land use and soil types.

4 PEACH PALM

4.1 Taxonomy

The Peach palm is placed in the Palmae family, Arecoidea, Cocoeae, in genus *Bactris* with specific name *gasipaes*. The author used in many publications is H.B.K., but Khunt is also mentioned. Some confusion exists about the correct genus name. Apart from *Bactris* in the majority of recent publications, *Guillielma* is used in others. The popular name in Central America is commonly Pejibaye. 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). These names mostly refer to the use of the fruits of the mature *Bactris gasipaes* palm.

4.2 Growing conditions and Morphology

B. gasipaes is a caespitose, monoecious feather palm (Figure 4.1) which has been cultivated since ancient time in Central America and South America. It grows best from sea-level till 800 meters. The species needs an annual rainfall of 2,000 to 10,000 mm, a warm climate (optimum temperature is 25° - 28° Celsius) and well-drained soils. During dry seasons decreases in yield can be high.

Figure 4.1 Young peach palms for palm heart production.

The peach palm can reach a height of maximal 20 meters with a stem-diameter of 10 to 25 centimetres. The stem is generally covered with spines, although spineless varieties exist. It develops suckers at the base of the stem. All suckers together form the "cepa". After minimal three years of germination the first flowers appear. The raceme has bisexual flowers and produces 10 - 120 fruits, weighing 1.5 - 18 kg. Production can go on for 50 to 75 years.

The young palms can also be harvested after 1,5-2,5 years for palm heart. The pseudostem is cut and the white centre, consisting of the growing point plus soft, undeveloped leaves, is extracted.

4.3 Peach palm cultivation

The advised cultivation techniques for peach palm differ depending on the intended product: fruits or palm heart. In the description below only the techniques for palm heart are mentioned.

Field selection.
Preferably fields should have good drainage conditions, and be reasonable fertile, on flat areas and below an altitude of 800 m above sea level. However *B. gasipaes* is also performing rather well on rather poor, acid soils and on slopes.

Nursery.
The seeds are germinated in plastic bags or on germination tables. Often the seeds are treated with fungicide. Visible germination starts after 1.5 - 2 months. A couple of weeks after germination the seedlings can be placed in special plant beds, with a plant distance of 40 cm. A nursery also can exist of plastic bags filled with soil and seed. The plants need shade until they reach a height of 20 cm (Roeland, 1994).

Transplanting.
When plants are transported to the field care should be taken, to avoid damage to the roots. Holes of 20 cm * 20 cm * 20 cm are dug and plants are taken from the bags and placed in the holes. Transplanting preferably takes place when the soil is humid and the weather is rainy or cloudy. Transplanting just before the dry season should be avoided. Fertilizer can be given at transplanting or later.

Planting density.
The planting density advised nowadays is 5000 pl/ha (2 m between rows and 1 m between plants). Higher densities are possible, but is not advisable in view of the spines that negatively affect the ergonomic conditions for labourers. Often circa 4000 plants / ha are planted now to ease working. Lower densities are also observed (Jongschaap, 1993). Previously only a limited amount of shoots was retained, but presently no thinning takes place (all the shoots are maintained), because research has shown that this did not influence the production negatively (Agropalmito

pers.comm.,1994).

Inter-cropping.
In peach palm inter-cropping is practised in the first or second year after transplanting. Also inter-cropping with fruit trees is practised. On sites with a slope it is recommended to inter-crop peach palm with species that cover the ground well. Examples of inter-crops are maize and beans. Beans are more preferable in terms of erosion control, because they cover the soil better (ANAI, 1986). Studies of inter-cropping with arazá (*Eugenia stipitate.* Mc Vaugh) resulted in a superior yield of peach palm (Picón de Esteves and Neyra, 1991). Agro-forestry studies showed that a mixed system with peach palm, *Inga edulis*, *Cedrelinga catenaeformis*, and *Eugenia stipitata* produced a greater variety of products and production was more stable through time than the pure peach palm plantation (Arévalo, 1991).

Fertilization.
In the humid tropics, the high precipitation and high temperatures cause quick decomposition of the organic matter and rapid loss of nitrogen by leaching. Also potassium is prone to leaching, while phosphorus - especially on volcanic soils - can be fixed. Therefore fertilizer applications should be given frequently and in relatively small amounts. Table 3.1 shows recommendations for peach palm in Costa Rica.

Table 3.1 Advised fertilizer quantities (kg/ha.y) and application frequency (Jongschaap, 1994).

N	P_2O_5	K_2O	Source
200-400	200	150-300	ASBANA,1981
3 x 120	100	2 x 100	Mora Urpi et al, 1984
		275	ASBANA, 1985
4 x 120	4 x 240	4 x 120	ANAI, 1986
200-250	20	160-200	Herrera, 1989
4 x 125	4 x 150		Agropalmito, 1991

Weed control.
Peach palm is limited by the presence of weeds, especially of Gramineas. For this reason weed control is important. Chemical control is mostly done with Paraquat, followed by Paraquat + Diuron, and Glyfosate. Also manual weed control is practised, especially for the bigger herbs.

Pest and pest-control.
Very few pest and diseases are known to considerably effect growth of peach palm.

In commercial plantations therefor no control measures are taken. The taltuza (*Ortogeomys cherriei*) is a very common rodent and is the most important pest problem in peach palm. Apart from occasional hunting and trapping not much is done.

Harvest.
The harvest is done manually when stems have a diameter of circa 15 cm. Cutting is done with a machete (large cutting knife). The pseudo-stem is harvested and leaves are cut and left between the rows. The outer leaf-sheets are removed as well. The length of the harvested part is about 60-80 cm (Jongschaap, 1993). On good plantations, yields may be obtained that exceed 10,000 palm hearts/ha.year. Small holders, on average, produce only 6,500 palm hearts/ha.year mainly on less fertile soils. It is said that spineless varieties produce less suckers and thus have a lower palm heart yield (Roeland, 1994). In some field the number of shoots is kept constant; for example four shoots per "cepa". An other practice is that no thinning out takes place and all shoots are able to develop.

Post-harvest.
After harvesting, the palm heart has to be processed quickly in a factory to avoid oxidization and browning of the originally white palm heart. For this reason road-infrastructure, transport and canning facilities are essential components for the palm heart production. The net product is about 10 % of the harvested material, the rest is waste material.

4.4 Palm heart in the Atlantic Zone of Costa Rica

Plantations of palm heart are expanding in the Atlantic Zone and also many small farmers are planting (Tönjes, 1994). Prices of palm heart were high compared to other crops in 1992, but due to the higher supply they are getting lower. Most palm heart is sold to processing factories, mainly for export in cans and jars. The most important importing countries are the United States, Canada and France followed by other European countries (Tönjes, 1994).

4.5 Agropalmito

The experiment described in chapter 5 is situated in the fields of Agropalmito S.A.. Agropalmito is a fifteen year old daughter company of DEMASA, specialized in palm heart production. Agropalmito has two farms, situated in Sarapiqui and Guápiles, with 600 ha and 800 ha respectively. Recently in Guápiles a processing factory was build for palm heart. Till now the capacity is not yet enough and the majority of the palm hearts has to be transported to an other factory. One big problem of processing the palm hearts is the amount of refuse. The company will use a part as a base material for the production of carton, an other part will be used for fodder and of the remainder compost will be made.

In the plantation the Costa Rica Criolla land race is used, which is a mixture of plants with few, mediate and many spines. The planting distance is 2 m x 1 m, corresponding with 5,000 plants/ha. All the shoots are maintained.

Every day harvesting takes place. Each plot ('lote') is checked once a month on shoots ready to harvest. The total production per day is about 20,000 shoots for the Guápiles plantation. Agropalmito buys also shoots from small farmers. At each plot herbicide is applied, also every month. For this a mixture of Galdoprim (Paraquat and Diuron) and Gramoxone (Glyfosate) is used. Manual weed control includes also a check for larger weeds, and cutting them down with a machete once in 2 or three months. Four times a year fertilization takes place. The total amount is 500 kg N/ha.year and 600 kg $P_2O_{2/ha.year}$ (see also Table 3.1).

In the fields of AGROPALMITO experiments have been done with a nitrogen fixing cover crop to control the amount of weeds. Unfortunately the weeds were much stronger than the N-fixating cover crop. Now experiments are running to investigate the amount of suckers a plant produces when the plant is cut down to the ground and the effect of shadow and fertilizer on the amount of developed shoots to get an idea of the relation between light and amount of shoots. Also the effect of growth hormones and micro nutrients are investigated to be able to improve the crop management. Agropalmito is developing a method for conserving palm heart (in water) in between the time of harvesting and processing.

An employee of Agropalmito is paid about C 1,800 a day, independent of the amount he harvests. They work 6 days a week. Agropalmito pays social security and insurance and offers their employees sport facilities, recreation infrastructure, transport to the field, material needed for work (boots, safety gloves and machete), medical service at the office during working days, economical help in case of marriage and birth and payment during vacations (12 to 20 days/year depending on the amount of years worked for Agropalmito).

5 THE MULCH-EXPERIMENT

5.1 Introduction

Mulching - covering the soil with some organic material- is a technique which has enjoyed considerable research interest during the past decade, particularly in connection with minimum tillage and erosion control (Beets, 1990). It is claimed that mulching improves soil fertility, soil microclimate, enhancing soil life and structure, conserving soil moisture, controlling soil erosion, preventing damage by impact from solar radiation and rainfall (Reijntjes, et al., 1992).

Mulch can be defined as a shallow layer at the soil/air interface with properties that differ from the original soil surface layer. This mulch layer can be formed by tree leaves, grass, straw, (inter)crop residues, prunings, weeds, ash, animal dung and household rubbish (Reijntjes, et al., 1992).

The following types of mulch can be distinguished (Beets, 1990);

1. Imported mulch; material that has been taken from elsewhere.
2. In situ, dead mulch; dry crop residues and leaves.
3. In situ, live mulch; living plants that grow between the crop,normally leguminous species.

The effects of mulch depend on its composition and colour, the amount applied, the timing of application and the rate at which the mulch decomposes. This rate depends, in turn, on the form and timing of application and the physical and chemical conditions in the soil and air (Reijntjes, et al., 1992).

The reason to use mulch vary with the environmental conditions. In the humid tropical climates there is no positive effect on the water balance to be expected from reduced evaporation. On the other hand improved infiltration rates can influence the water balance and can decrease erosion. No effect of reduced soil temperature is to be expected, because the maximum soil temperatures in the humid tropics are not extreme. The main effect of mulching in the humid tropics is likely to be the build up and maintenance of a flourishing soil (micro) fauna and flora (Guiking and Stomph, 1993). This is the main hypothesis for the design of this experiment. A good management of soil flora and fauna might result in a higher soil porosity and a higher amount of soil nitrogen by decomposition of the mulch material. A positive effect of higher porosity would be a more evenly and intensive rooting pattern, resulting in a higher nutrient uptake by the plant, although on the other hand a higher porosity might enhance losses of nitrogen through leaching (Guiking, 1994).

Peach palm for palm heart production is cultivated in the humid tropics and produces its own mulch. For this reason peach palm for palm heart is a suitable crop to test the hypothesis that mulching results in an improved soil flora and fauna, resulting in a higher soil porosity (a better structure) and a better crop growth.

Under crop management practised in the palm heart plantation, the soil receives crop residues from the crop, a so called self mulching system. The mulch consists of leaves and discarded disks of harvested palm hearts and is produced during harvesting. The plants receive N and P fertilizer. For Agropalmito this happens 6 times a year (6 x 125 kg N/ha/year and 2 x 150 kg P_2O_2 /ha/year). The N fertilization can influence the decomposition rate of organic matter and is for this reason of interest in the mulch experiment, where recycling of nutrients will be investigated.

To investigate the improvement of the soil flora and fauna and structure measurements have to be done. Measurements include dry bulk density, water holding capacity of the profile between 10 and 1600 kPa, soil penetrability, infiltration rates, break down of the mulch, nutrient status of soil and mulch, root proliferance studies, production of harvestable product. For some of these measurements destructive methods have to be done, like digging holes to determine pF curves. These measurements can be done at the end of the experiment. Unfortunately it is not done before the start of the experiment, but a part near the plots outside of the experiment can serve as the starting point.

In view of above, three aspects seem worthwhile and manageable to be studied in palm heart plantation;

1. the dynamics of soil water suction in time,
2. the crop growth, production and nutrient uptake,
3. the decomposition rate of the mulch.

These aspects within a field with varying amount of mulch and N-fertilizer.

An experiment was set up in an existing palm heart plantation (Kamstra, 1994). Representative sites were selected within the palm heart plantation and daily management of the experiment was started in May 1993 and continued till now (Bruinink, in prep., Van Horen, in prep). In July 1994 tensiometers were installed (Van Horen, in prep). This report describes the experiment from August until December 1994, and the methods to quantify mulch production and the decomposition rate of mulch.

5.2 Materials and methods

Experimental set up and daily management.

In an existing palm heart plantation of Agropalmito S.A., located in Guápiles, Costa Rica, two fields were selected (Kamstra, 1994), differing in soil type and age of establishment (Appendix I). In each field a 3 by 3 factorial experiment was laid out with four replications per field (Maps are in Appendix II).

Treatments (Table 5.1) were all combinations of 3 mulching levels (zero, normal and double) and three nitrogen fertilization levels (zero, 6 x 62,5 kg/ha.y and 6 x 125 kg/ha.year) the latter being the normal application practised by Agropalmito. Zero mulch means that all the leaves and rest of the stem materials (sheaths) are transported to an adjacent plot. The plot that receives the extra mulch is called the double mulch plot. Normal mulch treatment means that no mulch is transported, nor is added (the normal situation).

Location of the treatments within the blocks was not completely randomized since the double mulch plots had to be located directly up or down the rows from the zero mulch plots in order to facilitate transport of mulch. Each plot comprises 5 x 5 plants which amounts to 62.5 m² at the planting distance of 2.5 m between and 1 m within rows (Figure 5.1). The 9 innermost plants form the net plot, where border influences are expected to be negligible. One plot exist of four complete lanes ("calles") and two halfs. These halfs form the border of the plot. Samples of fresh mulch material (leaves and sheaths) were taken in calle 1 till 4. Sub-samples of plant and mulch material are only taken from the innermost "calles", indicated as calle 2 and calle 3. In the field the plots are marked by wooden posts, with signs indicating the treatments (Table 5.1).

Table 5.1 All combinations of the three levels of the two factors; mulch and N application with the indication used in the field. 0, 1, 2 indicate respectively mulch removal, no mulch removal and extra mulch. The bottom marks indicate the amount of fertilizer.

N fertilization	0	6 x 62,5 = 1	6 x 125 = 2
MULCH[1]			
zero	0	0 1	0 2
standard	1 0	1	1 2
double	2 0	2 1	2

[1] zero : all mulch is removed after harvesting
standard : no removal nor addition of mulch
double : addition of the mulch that is removed from the zero mulch field with same fertilizer treatment in the same block.

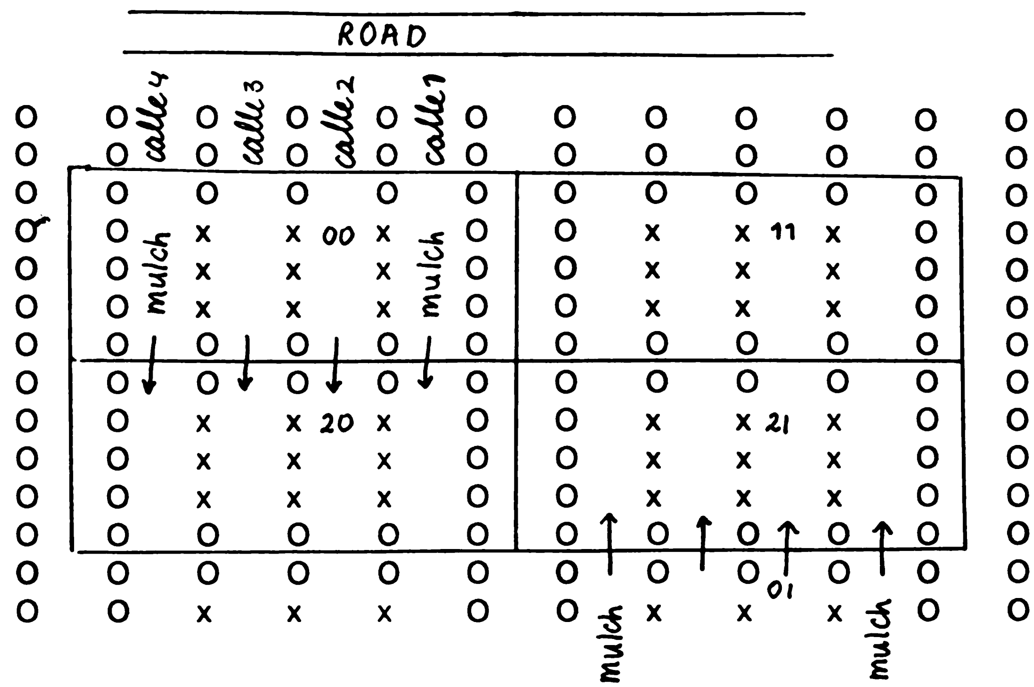

Figure 5.1 Set-up of a plot: 5 x 5 plants.The x indicate the net plot.

Once every two months the field is fertilized with N (Ammoniumnitrate 33.5% N). The plot amount is 25 g Ammonium nitrate per plant. Twice a year the experiment is fertilized with 25 g Triple Super Phosphate (ISP) per plant (TSP 46% P_2O_5 = 20.1% P).

Each month the shoots are harvested. One to two days after harvesting, mulch samples are taken and the mulch of the no-mulch plot is transported to the neighbouring double-plot. The mulch is spread out evenly per calle. When necessary,herbs are cut with a machete or herbicide is applied (a mixture of Gramoxone and Galdoprin (Paraquat, Diuron and Glyfosate) diluted in water (1:50)). In Appendix III all the activities are listed in chronological sequence.

Soil water conditions

No destructive measurements can be done until the end of the experiment, which means that within the field no Pf curve can be determined. Therefor only the soil suction is measured. Soil suction indicates the availability (the force a plant has to overcome to get water) of water for the plant, but not the amount of water available. Water is available between a pressure of -10,000 and -16,000 Pa equivalent to -100 and -160 mbar and Pf 2 -Pf 4.2. Above -10,000 Pa there is a shortage of oxygen, below -16,000 Pa the force, that the plant has to overcome is too high. To indicate soil water pressure tensiometers are used.

Tensiometers (vacuum-gauge, (Klute, 1986) produced by Eykelkamp, the Netherlands) are placed in treatments 2 0 (double mulch, no fertilizer), 0 (no mulch, no fertilizer), 2 (double mulch, normal fertilizer), 0 2 (no mulch, normal fertilizer) in one plot of the experiment. To enable quantification of the effect of depth and distance from the plant, tensiometers are put at different depths (20, 30 and 50 cm) and different distances from the plant (10, 20, 30 and 40 cm) (location see fig 5.3). The tensiometers are protected by pegs connected with a rope. Reading of tensiometers was done once a week or after a change in weather conditions ("Tensimeter"-soil and measurement systems) (Appendix IV).

Crop growth, production and nutrient uptake

Harvesting of palm hearts is about once a month, with field II being harvested two weeks later than field I. Peach palm which has a diameter of about 10 cm is cut near ground level and one meter higher. Leaves and outer leave sheaths of the stem ('sheaths') are separated and left in the field.

In the experiment harvest is always done by the same man, an employee of Agropalmito, to avoid variation in harvest method and to ensure that it is comparable to the standard procedures in the commercial part of the plantation. Per plot, the number and total weight the harvested part of the peach palm (shoots) are determined using a balance with a precision of 25 gram.

Within one day after harvesting samples of the fresh mulch material are taken. For the four innermost calles the leaves and sheaths are separated collected separately and weighted each on a balance with a precision of 0.1 pound (0.545 gram). The total weight of both mulch fractions (leaves and sheets) is determined. A sub-sample is taken of the leaves from calle 2 and 3. The leaves are cut in small parts and mixed where after the sub-sample is taken. This sample is dried in a stove during 3 days at a temperature of 65° C to determine the dry matter content. Sheaths are treated in the same way.

Per month one double mulch ánd its neighbouring zero mulch plot both with the same N treatment are sampled. After weighing and taking a sample the mulch of the zero mulch plot is transported to the double mulch plot of which the mulch already has been weighed (e.g. A00 and A20 = No mulch, no N fertilizer and Double mulch, no N fertilizer).

The sequence of sampling is as followed first the normal situation (01) (one plot per block), one month later the double mulch no fertilizer (+0) plot with its no mulch no fertilizer (↑0) plot and than the double mulch standard fertilizer (+1) plot with its no mulch (↑1) plot is sampled.

Samples are analyzed on nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and calcium (Ca) at the laboratory of CORBANA in La Rita, Costa Rica. Data in Appendix IX.

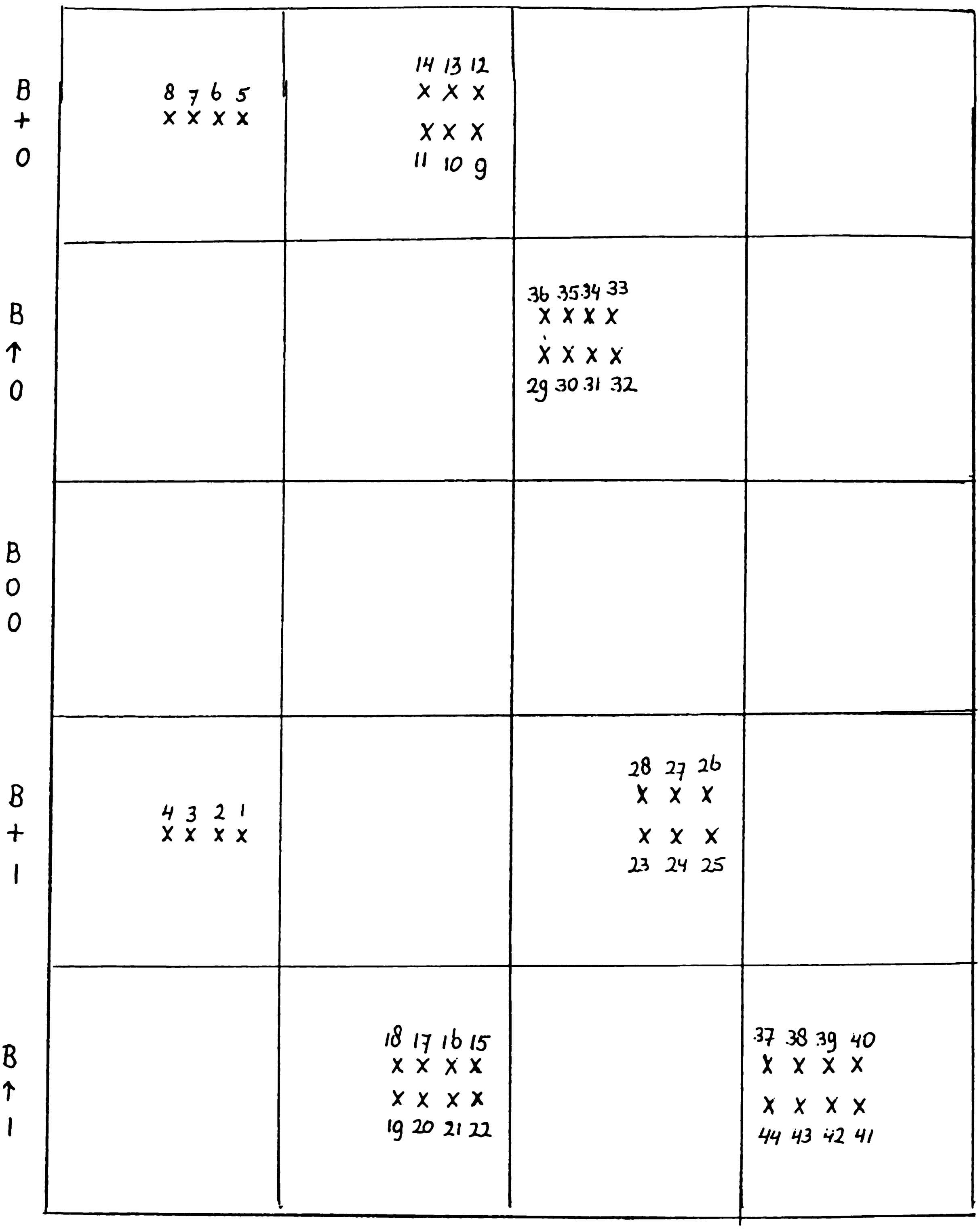

Figure 5.3 Tensiometers in Field 2. The numbers indicate the depth of the tensiometers.

Decomposition rate

To determine the decomposition rate of the mulch that remained in the field, a method was tried out whereby the old mulch was sampled one day prior to harvesting. This was done by collecting the total amount of mulch from each of the four innermost calles (with a mould). The old mulch was weighed. Sub-samples for determination of dry matter and nutrient content were taken from the old mulch of 'calle' 2 and 3. The dry matter content is determined in the same way as for the mulch production calculation.

Unfortunately, this method did not work. After one month the leaves and sheaths are integrated with the soil, and because of the high humidity soil and leaves/sheaths cannot be separated. For this reason determination of the composition rate was not continued.

Statistical analyses

SPSS (Norusis, 1990) (SPSS/PC+™ 4.0) was used to perform the statistical analyses. Analyses of variance (ANOVA) over the entire time of the experiment (of which data were available) was performed for soil pressure by mulch treatment and depth, to determine the relation between soil pressure on one side and mulch amount and depth on the other side. ANOVA was also performed for soil pressure by mulch treatment and distance to the plant, to determine the relation between soil water pressure on one side and mulch treatment and distance to the plant on the other side. A more complete analysis was impossible due to constraints in SPSS. (Other statistical programs were not tried).

ANOVA was performed over the entire time of the experiment (of which data were available) with harvested palms by nitrogen and mulch treatments.

A linear regression analysis (in QPRO) was performed with leaves and sheaths as independent factors and amount of harvested peach palms as dependent variable, to determine the relation between the number of harvested peach palms and the weight of the leaves and sheets .

5.3 Results

Soil water conditions.

Some effect of depth and distance from the plant was discovered in the dynamics of the soil water suction. Here two examples are shown. Data of all observations are in Appendix IV.

For the 2 0 plot (double mulch, no N-fertilizer) where tensiometer tubes are placed, there is a clear difference between the soil suction pressure on the two different depths. At the depth of 50 cm the suction is generally more negative. Far from the plant the suction seems less negative (Figure 5.4).

For the 0 plot (no mulch, no N-fertilizer) there is no clear difference. All the soil suction pressures variate in the same way. Neither any effect of the distance to the plant can be recognized (Figure 5.5).

ANOVA was done over the entire measuring period for soil pressure by mulch treatment and depth. (Inputs and outputs of SPSS are in Appendix V). ANOVA resulted in a significant relation between soil pressure and mulch treatment and between soil pressure and depth of the tensiometer in the soil. There was no significant relation between the soil pressure on one side and mulch amount and distance to the plant on the other side.

ANOVA was done over the entire measuring time for soil pressure by mulch treatment and distance to the plant. This ANOVA did not determine any significant relation between soil pressure, mulch treatment and distance to the plant.

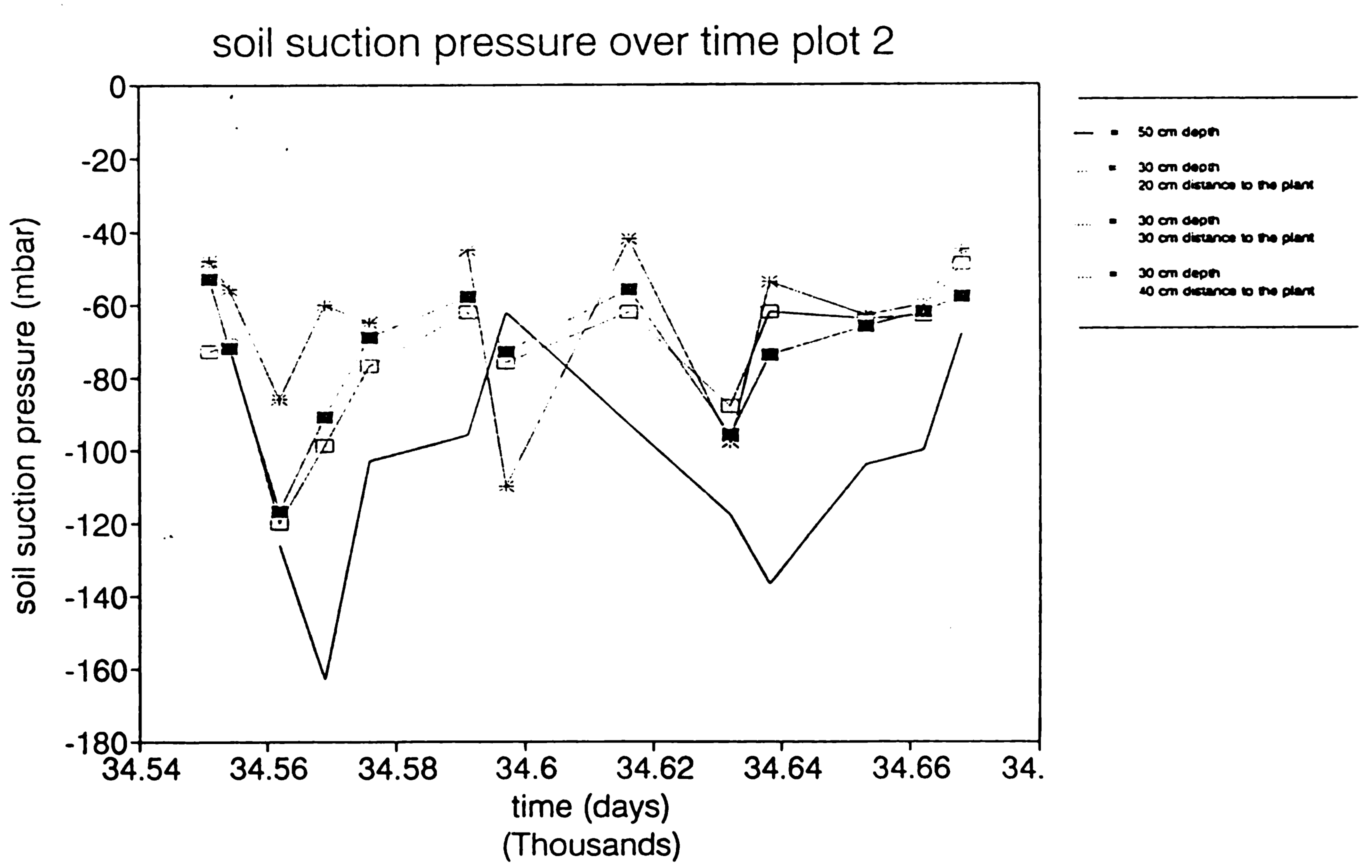

Figure 5.4 Soil suction over time tensiometer group 2

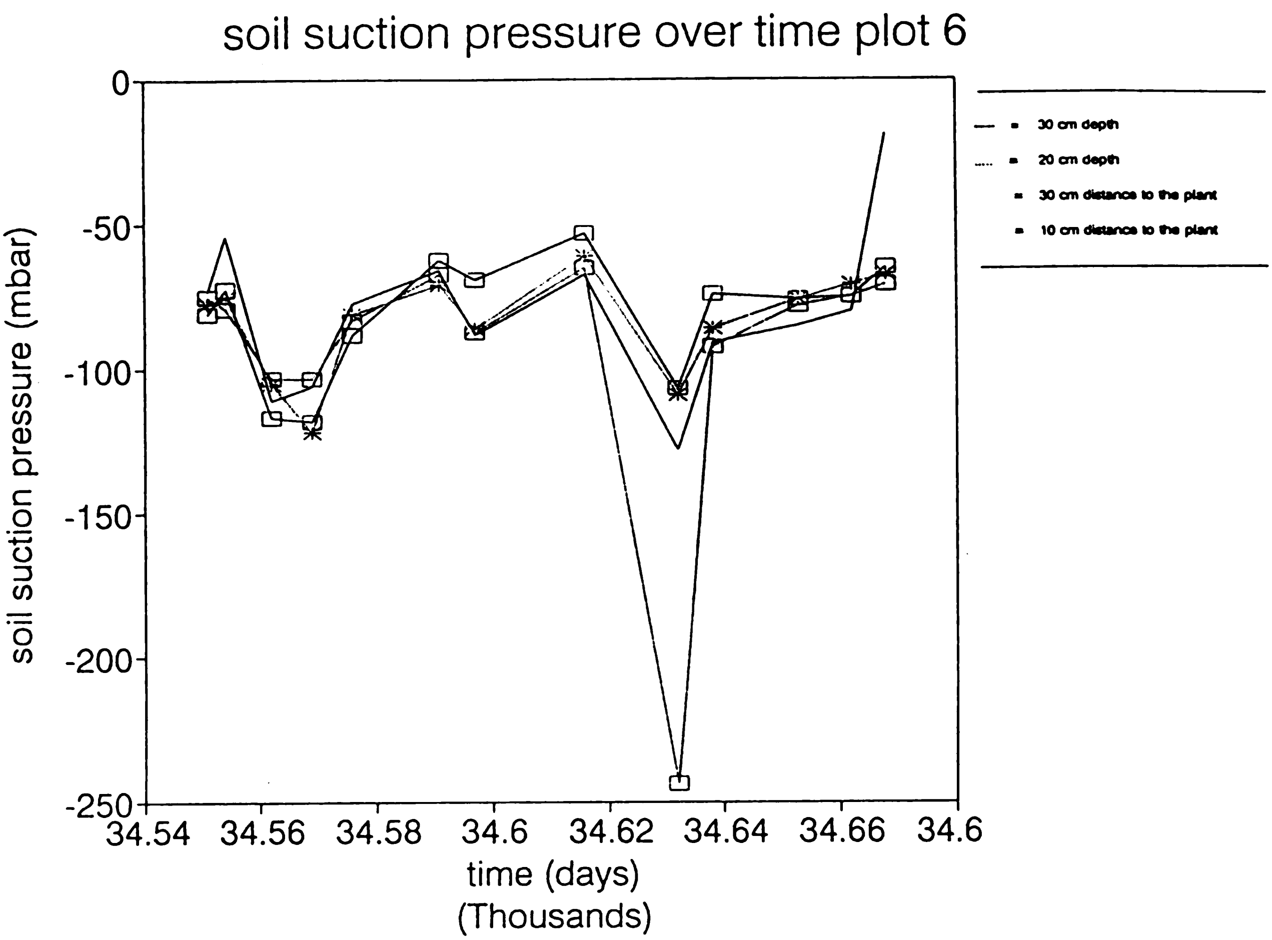

Figure 5.5 Soil suction over time tensiometer group 6

Crop growth, production and nutrient uptake.

The peach palm production does not seem to be affected by treatment (see Appendix VI for ANOVA results). The only relation that was statistically significant was a difference between blocks for total palm heart production. Here two examples are shown of the total palm heart production (in kg) per block; block B in field I and block D in field II (figure 5.6). Only these two blocks are shown, because they have opposite relations. In block B there seems to be a negative relation between the treatment and the total palm heart production. The total palm heart production is higher in the treatments without fertilization and without mulch. This is completely against the expected effect that fertilization and mulching will have a positive effect on production. This trend nor any other can be seen in block II.D.

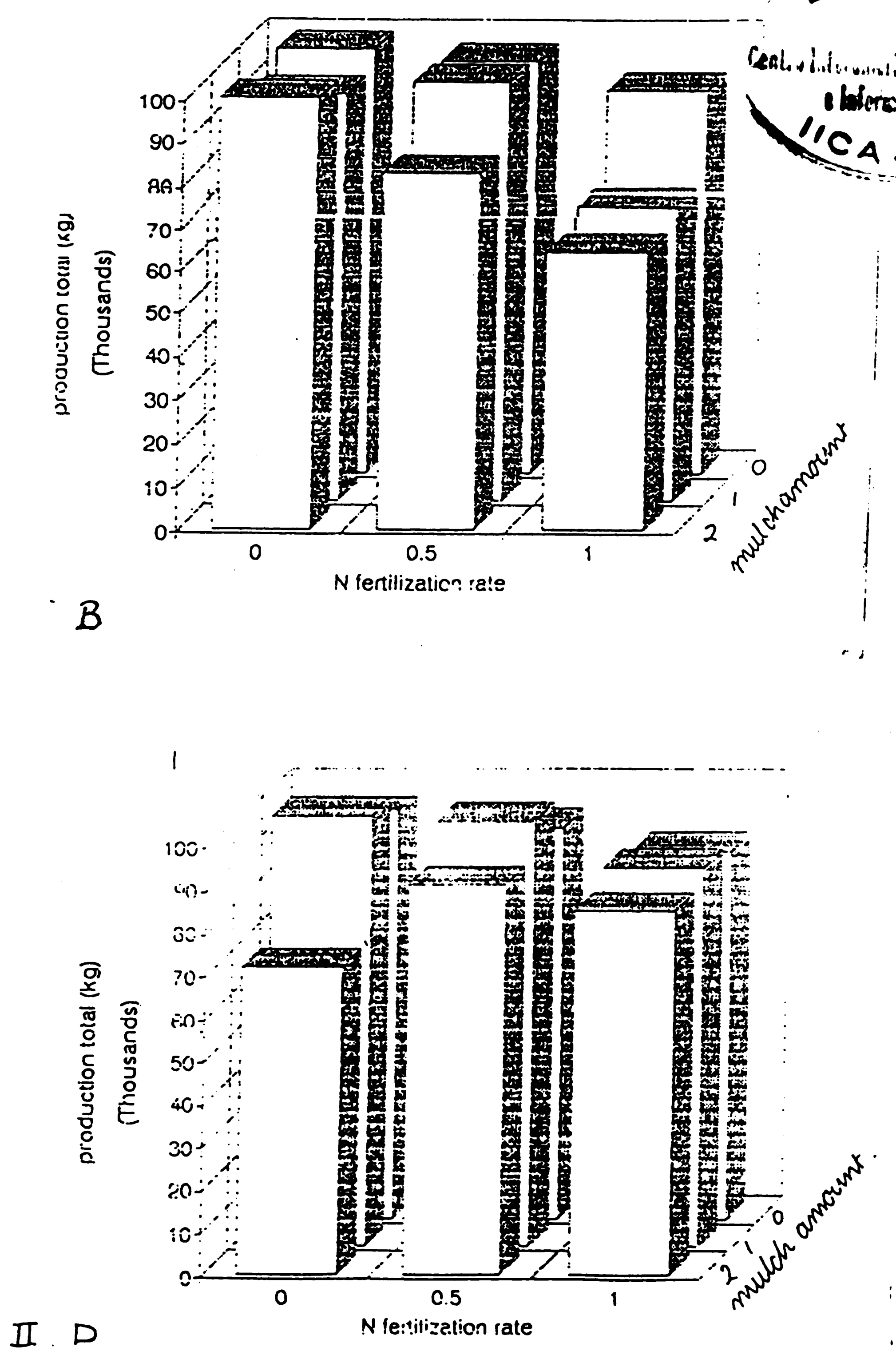

Figure 5.6 Total peach palm production of plot B field I and plot D of field II related to N fertilization rate and mulch amount.

The mulch production is dependent of the number of shoots harvested. The data collected till now (Table 5.2) are scanty. These data are worked out to get a first impression of the data collected till now.

Table 5.2 mulch production for field I and field II
0 indicates no mulch; 2 indicates double mulch; 0 indicates no N fertilization; 2 indicates standard N fertilization

plot	material	field I			field II		
		0	0 1	2 1	0	0 1	2 1
A	leaves	8.2	6.5	4.4	6.2	7.8	7.0
	sheaths	4.1	1.3	1.7	3.7	3.8	2.1
	total	12.3	7.8	6.1	9.9	11.6	9.1
	# shoots harvested	13	6	10	16	18	12
	kg shoots	15.5	4.3	11.2	17.8	19.4	15.4
B	leaves	6.8	6.7	4.4	4.2	4.7	6.6
	sheaths	1.8	1.6	1.2	3.8	1.3	1.8
	total	8.6	8.3	5.6	8.0	6.0	8.4
	# shoots harvested	10	8	7	12	8	8
	kg shoots	11.6	7.1	7.8	14.3	6.5	11.0
C	leaves	8.7	4.3	4.0	3.2	4.2	4.1
	sheaths	3.3	1.8	1.1	1.8	1.2	1.3
	total	11.0	6.1	5.1	5.0	5.4	5.4
	# shoots harvested	12	7	6	7	8	8
	kg shoots	13.2	7.0	6.0	8.0	9.1	6.6
D	leaves	8.4	4.1	6.1	7.0	6.0	6.8
	sheaths	2.9	1.8	1.3	3.3	2.3	1.6
	total	11.3	5.9	7.4	10.3	8.3	8.4
	# shoots harvested	13	6	7	13	8	10
	kg shoots	14.2	5.1	7.3	17.5	9.5	12.2

To analyze the relation between the amount of harvested shoots and the total mulch production, regression analyses in QPRO (table 5.3) was preformed for number of harvested shoots as independent factor and the total mulch production (in kg d.m.) as dependent factor.

Homogeneity of the X-coefficient was examined (Gomez and Gomez, 1984) to determine if there is a relation between the amount of harvested shoots and the amount of mulch for the different treatments. In other words if under different treatment the amount of mulch produced is different. The hypothesis of significant equivalence of the X-coefficient could not be rejected (Appendix VII). This means that there is no significant difference between the α 's (x-coefficient) and that means no significant difference between the treatments (Appendix X).

Also the hypothesis of $\beta = 0$ (this means when there are no shoots harvested there are no leaves and sheaths) is investigated (Gomez and Gomez, 1984). This hypothesis cannot be rejected for no mulch no fertilizer (0) and double mulch normal fertilizer (2). For no mulch normal fertilizer (0 2) the hypothesis $\beta = 0$ is rejected (Appendix VIII), indicating a possible non linear relation between mulch production and harvested shoots.

The results of the chemical analyses (Appendix IX) of the mulch material could not statistically be analyzed, because of a shortage of degrees of freedom.

5.4 Discussion

It seems that the treatment with double mulch tends to increase the soil suction pressure, this means that the soil becomes drier. It is not sure whether this effect is due to the mulch effect. The area of the tensiometers does not receive leaves or sheaths because the protection of the tensiometers, prevents the mulching of the soil at the sites of the tensiometers.

In general the set up of the soil water condition research should be carried out differently. With described methodology the data do not say anything about the soil suction dynamics. Only a trend can be analyzed. For a better valuation of the soil suction data, a more intensive reading of the tensiometer should be done, kept up with the total amount of rainfall in time.

Differences in soil moisture pressure over depth can be explained by the fact that little rainfall only influences the soil up to 30 cm depth, but heavy rainfall influences the soil also at deeper layers.

After one year of managing the experiment, no effects of the treatments can be recognized in total yield of palm heart. The only relation found was the relation between total yield of peach palms and the block. This indicates that the set-up of the field in blocks is useful. ANOVA with all variables (yield by block, amount of mulch and N-gift) was not possible, because of a shortage in memory of the computer. Other statistical techniques might be needed to analyze the results.

A relation of mulch production and nutrient uptake could not be distinguished. Regression analyses did not result in significant difference of mulch production per harvested shoot. A shortage of available data and repetitions can be a reason.

The main conclusion until now is that no real significant differences of the different treatments could be recognized. The mulch has some effect on the soil suction characteristics, but how much and how related is not worked out. The whole experiment considered, more time and data are needed to be able to distinguish any effects of the treatments.

6 PERSONAL EXPERIENCE

After I had spent 6 weeks in Senegal (in the beginning of my study) I thought, I never would go to the tropics any more. But during the years following, new interest arose and I thought about going to Latin America, an other continent, a new tropical experience.

I was interested in a investigation in which agronomic and soil aspects were combined. I found a suitable experiment within the Atlantic Zone Programm, a mulch experiment within a palm heart plantation.

A language course in San Jose (after a basic course in Wageningen) improved my knowledge of the Spanish language a lot and the social contacts in Guápiles, Heredia, Turrialba, Villafranca and Santa Cruz really helped me to feel comfortable and able to speak a reasonable mouth full of Spanish.

During my practical work often Don Migael and 'Gordo' accompanied me. They were a source of inspiration and humour. Without them it would not have been as nice as it was. I found out I like to be in the field. I like to see the birds, the butterflies, the lizards and even the snakes. I like to hear people's stories and people's ideas about farming, living and enjoying nature. Don Migael, 'Gordo' and other field workers helped me and learned from me, but in exchange I learned even more from them. In this social climate I like to work and I like to live.

My interest are broad. Besides my field experience I learned of analyzing data (SPSS) and wording the outcome in a report. I received a lot a support from either the Costa Rican staff as well from my supervisors. I dealt with conflicts between them and learned from it. Managing an experiment can't be done when there is a large distance between the supervisors, in physical ánd personal terms.

I visited farmers, milked cows, made cheese, slaughtered a pig and a chicken, selected seeds and sowed beans, fished, rode a horse, hiked and enjoyed it all. I spoke with the farmers about their problems, their crops and cattle.

I visited a FAO forestry project in Ecuador and saw how it worked out. I learned about rapid rural appraisal and participation. I joined the official opening of a local nursery, and heard the things the local people had learned during courses.

There is a lot to do and a lot has to be done. I would like to work in a foreign country for some time. I like to work with people and to learn from them, to enjoy the atmosphere and nature. To enrich myself with the experiences and I hope I can mean something for others.

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List of Appendici

APPENDIX I: Soil discription field I and II of the mulch experiment

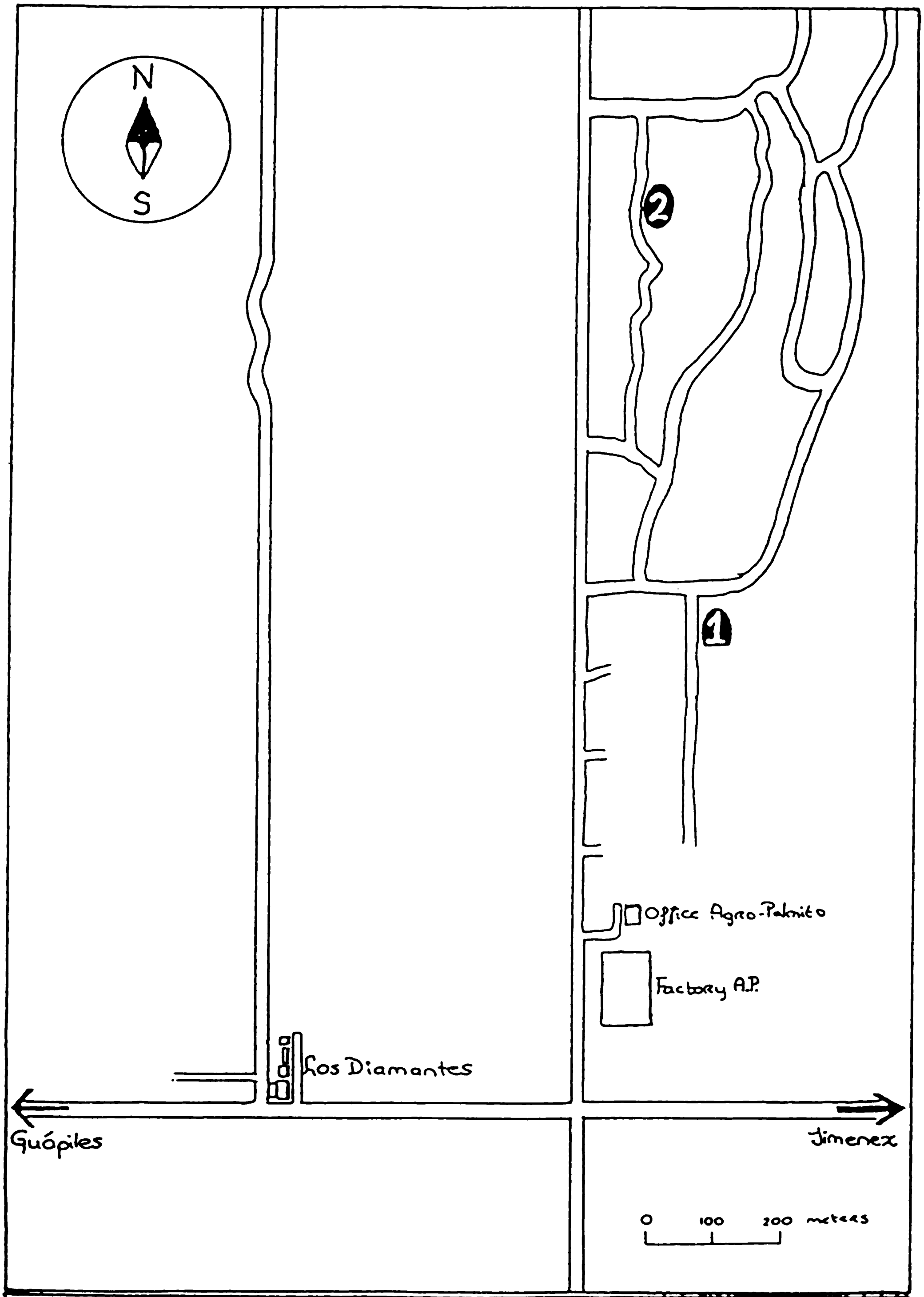
Profile Number: Finca agropalmito field 1.
Soil unit: Iroquois
Soil taxonomic Classification: U.S.D.A.: Typic Hapludand, coarse loamy, isohyperthermic, perudic
Date:940302
Authors: E.S. Bruining and P.C. van 'Horen
Location: 2.5 km east of Guápiles (Pococi), 1.5 km north of road Guápiles-Rio Jimenez, Province of Limon
Eleveation: 220 m
Map sheet number: 3446 IV
Coordinates: 562.25-244.90
Soil Climate: Isohyperthermic
Topography: Undulating
Landform: Volcano
Land element: Footslope
Position: Middle slope
Gradient: Gently sloping (5 %)
Form: S
Micro-topography: LE
Land Use: AP1, Palmito
Human influence: FE
Vegetation: Palmito, hight 1.5m - 2m
Grass cover: 1 (1%)
Parent material: Lahar, mudstreams, VO
Effective soil depth: Moderately deep (-70cm)
Rock outcrops: None
Surface coarse fragments: Abundant,Course gravel to stones
Erosion: No evidense of erosion
Surface sealing: None
Salt: None
Bleached Sand: None
Drainage Classes: Well drained
Internal Drainage: W
Groundwater: E, NK
Moisture conditions: M

Soil Horizon Description

Ah1	0-5 cm	Dark brown (10 YR 3/3) moist, silt loam; common, coarse gravel and stones; angular, moderately weathered; very fine subangular blocky; firm when moist, slightly sticky when wet, slightly plastic; none pores; none cutanic features; none cementation and compaction; many fine and medium sized roots; clear, smooth boundary.
Ah2	5-50 cm	Dark brown (10 YR 3/4) moist, silt loam; common to many coarse gravel and stones; angular, moderately weathered ; very weak subangular blocky; very friable when moist, slightly sticky when wet, slightly plastic; medium porosity with many, very fine pores ; none cutanic features; no sementation and compaction; common to few, fine and medium sized roots; gradual smooth boundary.
Bh	50-70 cm	Yellowish brown (10 YR 5/6) moist, silt loam; many stones and boulders;angular, moderately weathered; very weak subangular blocky; very friable when moist, slightly sticky when wet, slightly plastic; medium porosity with many, very fine pores; none cutanic features; no sedimentation and compaction; few fine and medium sized roots; abrupt and wavy boundary.
Bc	70-75+cm	Dull yelow orange (10 YR 6/4) moist,sandy loam; abundant fine gravel to large boulders; angular, moderately weathered; very weak subangular blocky; very firm when moist, slightly sticky when wet, slightly plastic; medium porosity with common, very fine pores; no cutanic features; no sedimentation and compaction; very few fine and medium sized roots.

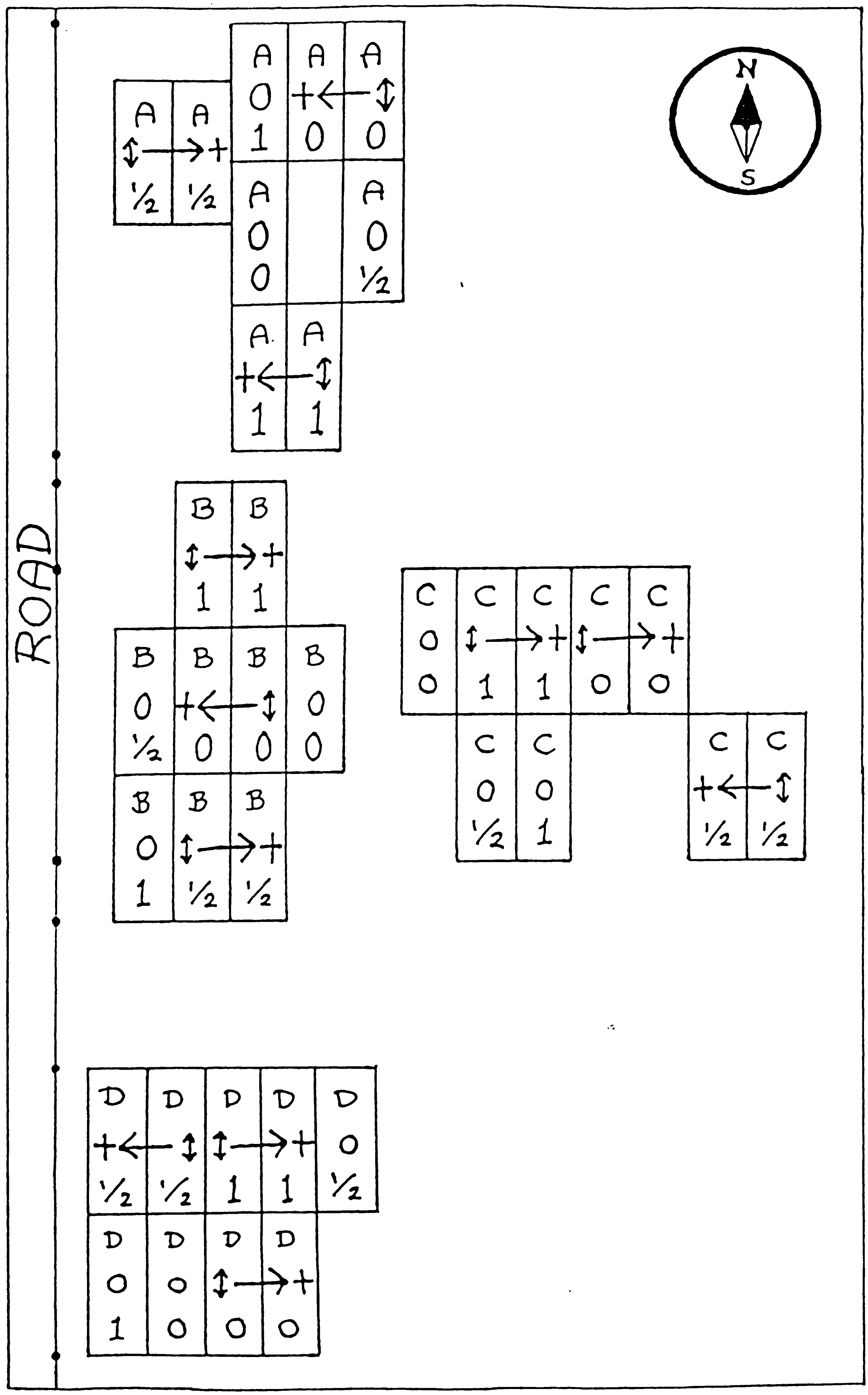
APPENDIX II: Maps of the fields

MAP 1
Location Of The Experiments



Explanation of the numbers: 1. First mulch experiment
2. Second mulch experiment

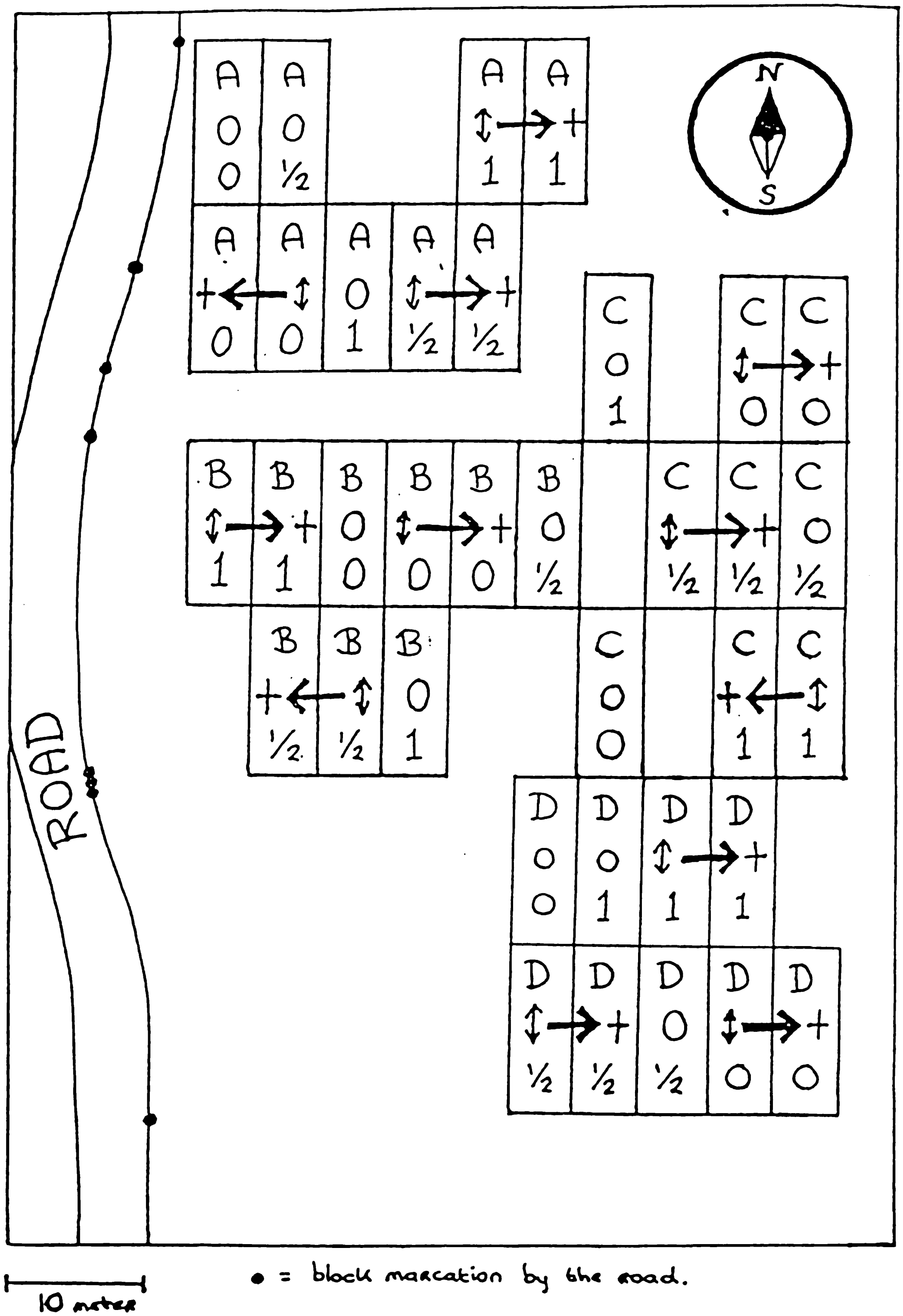
Working Map Field 1



10 meter

• = block marcation by the road.

Working Map Field 2



The markation on the poles surrounding the experimental blocks. The marks are described in top-down direction, similar with the poles.

TYPE OF MARKATION	MARKATION	DESCRIPTION
	White band	For improved visibility
BLOCKNUMBER	A	First block
	B	Second block
	C	Third block
	D	Fourth block
MULCH LEVEL	↑↓ ↓	Mulch is carried to the observer - zero mulch level
	↑↓ ↑	Mulch is carried from the observer - zero mulch level
	O	No mulch transport - normal mulch level
	+	Mulch transport to this field - dubble mulch level
FERTILIZER LEVEL	O	No fertilizer application
	½	Half of the normal fertilizer application
	1	Normal fertilizer application
	White band	For improved visibility

APPENDIX III: Activities

FIELD I

26-07-94 Palm heart harvested.
29-07-94 Fertilizer applied (Nutran).

04-08-94 Herbicide applied.
17-08-94 Mulch transported (cleaning the fields).
31-08-94 Fertilizer applied (Nutran).
20-09-94 Herbicide applied.
21-09-94 Palm heart harvested.
22-10-94 Cleaning the fields.
25-10-94 Palm heart harvested.
26-10-94 Mulch samples taken.
27-10-94 Cleaning the fields.
22-11-94 Palm heart harvested.
23-11-94 Mulch samples taken.
24-11-94 Cleaning the fields.
26-11-94 Herbicide applied.
27-11-94 ERROR found.
Found the following plots applied with..............:
in block A ¡0, +0, 01, +1/2 and ¡1/2.
28-11-94 Marked the whole experiment with piles and rope.
20-12-94 Palm heart harvested.
21-12-94 Mulch samples taken.
22-12-94 Cleaning the fields.
09-01-95 Fertilizer applied (Nutran).

FIELD II

06-08-94 Fertilizer applied (Nutran).
24-08-94 Palm heart harvested.
25-08-94 Cleaning the fields.
19-09-94 Fertilizar applied (Nutran).
11-10-94 Palm heart harvested.
12-10-94 Mulch samples taken.
13-10-94 Cleaning the fields.
09-11-94 Palm heart harvested.
10-11-94 Mulch samples taken.
11-11-94 Cleaning the fields.
12-11-94 Herbicide applied.
13-12-94 Palm heart harvested.
14-12-94 Mulch samples taken.
15-12-94 Cleaning the fields.

03-01-95	Fertilizer applied (Nutran).
04-01-95	Palm heart harvested.
05-01-95	Mulch samples taken.
06-01-94	Cleaning the fields.

Each time after harvesting the selected 32 plants were marked with a ribbon. (Experiment: Leaf and shoot dynamics).

APPENDIX IV: Tensiometer data

tensiometers Field II

plek	buis nr.	diepte cm	mulch	fert	6 aug	8 aug	16 aug	23 aug	30 aug	14 sep (no regen)	20 sep	9 okt (no regen)	26 okt	31 okt (nat)	16 nov	24 nov	30 nov
1	1	60	+	1			-95	-121	-67	-73	-96	-63	-116	-69	-100	-96	-73
1	2	30	+	1	-79	-80	-124	-119	-71	-61	-60	-66	-103	-62	-78	-63	-67
1	3	30	+	1	-73	-95	-119	-121	-63	-63	-67	-63	-97	-68	-73	-67	-69
1	4	30	+	1	-48	-78	-102	-70	-70	-65	-62	-66	-106	-60	-69	-65	-62
2	5	60	+	0	-65		-126	-163	-103	-96	-62	-93	-118	-137	-104	-100	-68
2	6	30	+	0	-63	-72	-117	-91	-69	-69	-73	-66	-96	-74	-66	-62	-69
2	7	30	+	0	-73	-71	-120	-99	-77	-62	-76	-62	-88	-62	-64	-63	-49
2	8	30	+	0	-48	-66	-86	-60	-65	-46	-110	-42	-93	-64	-63	-60	-46
3	9	20	+	0	-73	-74	-127	-60	-63	-63	-84	-68	-161	-81	-79	-44	-26
3	10	20	+	0	-46	-49	-100	-81	-73	-66	-72	-49	-100	-72	-62	-65	-7
3	11	20	+	0	-69	-66	-126	-69	-83	-49	-70	-48	-72	-41	-62	-42	-6
3	12	60	+	0	-77	-114	-111	-66		-96	-106	-93	-133	-129	-111	-88	-26
3	13	60	+	0	-72	-61	-91	-114	-61	-94	-107	-89	-123	-119	-109	-86	-17
3	14	60	+	0	-92	-107	-119	-130	-102	-95	-111	-96	-116	-111	-106	-88	-20
4	15	20	-	1	-67	-64	-111	-95	-75	-45	-69	-60	-110		-61	-65	-42
4	16	20	-	1	-48	-77	-123	-96	-64	-37	-66	-46	-100	-35	-48	-62	-47
4	17	20	-	1	-65	-64	-129	-106	-60	-43	-73	-41	-141	-113	-81	-66	-63
4	18	20	-	1	-68	-79	-180	-164	-72	-62	-97	-60	-383	-376	-172	-68	-61
4	19	30	-	1	-70	-64	-110	-69	-68	-62	-62	-47	-79	-73	-74	-65	-73
4	20	30	-	1	-68	-77		-66	-78	-64	-79	-63	-107	-78	-67	-64	-67
4	21	30	-	1	-65	-70		-166	-77	-64	-86	-68	-164	-166	-94	-69	-49
4	22	30	-	1	-67	-76	-130	-244	-60	-60	-89	-67	-176	-296	-107	-66	-62
5	23	60	+	1	-66	-84	-116	-130	-95	-65	-103	-84	-116	-92	-103	-95	-41
5	24	60	+	1	-94	-84	-114	-137	-94	-67	-101	-87	-114	-71	-101	-91	-46
5	25	60	+	1	-69	-73	-105	-143	-89	-76	-96	-61	-116	-66	-99	-91	-42
5	26	20	+	1	-69	-74	-117			-37					-60	-68	-47
5	27	20	+	1	-66	-69	-107	-67	-69	-61	-67	-43	-72	0	-61	-49	-63
5	28	20	+	1	-63	-63	-116	-71	-68	-67	-65	-63	-74	-64	-63	-40	-48
6	29	30	-	0	-73	-64	-111	-105	-77	-66	-68	-67	-128	-91	-85	-60	-19
6	30	30	-	0	-81	-69	-116	-137	-77	-61	-78	-61	-121	-94	-84	-78	-29
6	31	30	-	0	-81	-72	-117	-118	-89	-62	-69	-63	-107	-74	-76	-75	-65
6	32	30	-	0	-69	-30	-111	-96	-71	-60	-81	-69	-112	-69	-73	-74	-68
6	33	20	-	0	-68	-60	-93	-100	-70	-65	-78	-67	-100	-75	-71	-69	-66
6	34	20	-	0	-77	-76	-105	-122	-81	-71	-86	-61	-103	-86	-76	-71	-67
6	35	20	-	0	-73	-67	-97	-123	-72	-66	-86	-60	-116	-100	-82	-74	-69
6	36	20	-	0	-76	-79	-103	-103	-83	-67	-87	-65	-244	-92	-78	-76	-71
7	37	20	-	1	-68	-68		-76	-79	-47	-64	-49	-132	-35	-68	-60	-66
7	38	20	-	1	-61	-64	-109	-45	-72	-41		-46	-79	-39	-49	-36	-68
7	39	20	-	1	-74	-62	-119	-68	-74	-43	-67	-46	-84	-38	-68	-63	-62
7	40	20	-	1	-65	-69	-148	-146	-79	-65	-68	-44	-126	-47	-67	-68	-64
7	41	30	-	1	-62	-81	-102	-116	-73	-69	-84	-61	-122	-131	-98	-61	-65
7	42	30	-	1	-70	-82	-66	-103	-70	-62	-76	-69	-111	-104	-89	-68	-69
7	43	30	-	1	-61	-69	-93	-121	-71	-62	-73	-68	-120	-131	-82	-67	-70
7	44	30	-	1	-68		-100	-98	-80	-61	-74	-61	-122	-121	-86	-71	-61

APPENDIX V: ANOVA input output tensiometer data

Page 11 SPSS/PC+ 12/20/94

SET /PRINTER ON.
ANOVA druk BY diepte(20,50) mulch(0,2).

'ANOVA' PROBLEM REQUIRES 73600 BYTES OF MEMORY.

Page 12 SPSS/PC+ 12/20/94

* * * A N A L Y S I S O F V A R I A N C E * * *

DRUK
BY DIEPTE
MULCH

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	39038.142	3	13012.714	11.678	.000
DIEPTE	37957.986	2	18978.993	17.032	.000
MULCH	15669.920	1	15669.920	14.063	.000
2-way Interactions	586.094	1	586.094	.526	.469
DIEPTE MULCH	586.094	1	586.094	.526	.469
Explained	39624.236	4	9906.059	8.890	.000
Residual	613979.145	551	1114.300		
Total	653603.381	555	1177.664		

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572 Cases were processed.
16 Cases (2.8 PCT) were missing.

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This procedure was completed at 11:06:19

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ANOVA druk BY mulch(0,2) afstand(10,40).

'ANOVA' PROBLEM REQUIRES 73600 BYTES OF MEMORY.

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* * * A N A L Y S I S O F V A R I A N C E * * *

DRUK
BY MULCH
AFSTAND

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	9248.828	4	2312.207	1.986	.095
MULCH	933.232	1	933.232	.802	.371
AFSTAND	3168.672	3	2722.89[illegible]	2.339	.073
2-way Interactions	6402.857	3	2134.929	1.833	.140
MULCH AFSTAND	[illegible]	3	2134.929	1.833	.140
Explained	15630.9[illegible]	7	2233.[illegible]	[illegible].92[illegible]	.0[illegible]
Residual	[illegible]7952.466	[illegible]	11[illegible]		
Total	653603.38[illegible]	555	1177.66[illegible]		

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572 Cases were processed.
16 Cases (2.8 PCT) were missing.

Page 18 SPSS/PC+ 12/20/94

This procedure was completed at 11:08:07

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APPENDIX VI: ANOVA input output production per treatment

```
ANOVA   total by block(1,4) mulch(0,2) nitro(0,1).

'ANOVA' PROBLEM REQUIRES .    5768 BYTES OF MEMORY.
```


* * * A N A L Y S I S   O F   V A R I A N C E * * *

```
        TOTAL
   BY   BLOCK
        MULCH
        NITRO
```

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
Main Effects	3611898584.85	6	601983097.46	2.110	.069
BLOCK	3085665701.49	3	1028555233.8	3.606	.020
MULCH	243132628.861	2	121566314.43	.426	.655
NITRO	283100254.507	1	283100254.51	.992	.324
2-way Interactions	4003237192.31	11	363930653.85	1.276	.267
BLOCK MULCH	2074634250.47	6	345772375.08	1.212	.317
BLOCK NITRO	1541929474.91	3	513976491.64	1.802	.159
MULCH NITRO	386673466.931	2	193336733.47	.678	.513

Source of Variation	Sum of Squares	DF	Mean Square	F	Signif of F
3-way Interactions	458043023.569	6	76340503.928	.268	.949
BLOCK MULCH NITRO	458043023.569	6	76340503.928	.268	.949
Explained	8073178800.74	23	351007773.95	1.230	.267
Residual	13692313624.2	48	285256533.84		
Total	21765492425.0	71	306556231.34		

72 Cases were processed.
0 Cases (.0 PCT) were missing.

This procedure was completed at 15:12:32

APPENDIX VII: Analyse X equivalence (Gomez and Gomez, 1984)

A?0 # shoots	kg d.s.		A?1 # shoots	kg d.s.		A+1 # shoots	kg d.s.	
13	12.3		5	7.8		10	6.1	
10	7.5		6	7.2		7	5.6	
12	12		7	6.1		6	5.1	
13	12.3		5	5.7		7	6.4	
15	7.9		16	11.7		12	9.1	
12	8		6	6		9	7.3	
7	5		8	5.4		6	5.4	
13	10.3		8	8.3		10	7.4	
11.875	9.4125	gem	7.625	7,275	gem	8.375	6.55	gem
40.875	51.56875	som @2	89.875	29.915	som @2	33.875	12.34	som @2
28.0125		som xy	42.425		som xy	18.05		som xy

A1	A2	A3
32.37119	9.888512	2.722214

B

44.98192

C

164.625

D

93.82375

E

88.4875

F

0.255895

Hypothese: ß1 = ß2 = ß3 F < F tabular

Hypothese is not rejected,

there is no significant difference between the α.

APPENDIX VIII: Analyse hypothese B = 0

Mulch production by number of palms

Hypothese: ß = ß = ß (Gomez and Gomez, 1984)

STEP 1
Total

A↑ 0 Y = 1.274312 + 0.685321 X

A↑ 1 Y = 3.675661 + 0.472045 X

A + 1 Y = 2.087454 + 0.532841 X

STEP 2

$$A1 = 760.33 - \frac{922^2}{1169} = 33.14$$

$$A2 = 453.3 - \frac{486.2^2}{555} = 27.37$$

$$A3 = 355.6 - \frac{456.9^2}{595} = 4.75$$

STEP 3

B = 33.14 + 27.37 + 4.75 = 65.26

STEP 4

C = 1169 + 555 + 595 = 2319

D = 760.3 + 453.3 + 335.6 = 1569.2

E = 922.2 + 486.2 + 456.9 = 1865.3

STEP 5

$$F = \frac{[D - (E^2/C) - B]/ (K-1)}{B/(n - 2K)} = 206.9$$

APP E f1 = (K-1) = 2 > 6.01
f2 = 18
206.9 > 6.01

CONCLUSION
The B values (RC) of the regression are significantly different.
The highest is B1 = A↑ 0
this means that more leaves have been produced per harvested shoot (less N and less leaves back to the soil means less nutrients ?)

APPENDIX IX: Chemical analyse results

material	field	block	mulch	nitro	N %	P %	K %	Ca %	Mg %	total dm	Ntot	Ptot	Ktot	Catot	
hoj	1	1	0	0	2.37	0.22	1.8	0.32	0.21	8.2	0.19434	0.01804	0.1476	0.02624	0.001479
cas	1	1	0	0	0.71	0.19	2	0.26	0.16	4.1	0.02911	0.00779	0.082	0.01066	0.000319
hoj	1	2	0	0	2.38	0.22	1.4	0.3	0.19	5.6	0.13328	0.01232	0.0784	0.0168	0.00069
cas	1	2	0	0	0.89	0.19	1.6	0.33	0.21	1.9	0.01691	0.00361	0.0304	0.00627	6.86E-05
hoj	1	3	0	0	2.16	0.18	1.5	0.3	0.19	8.7	0.18792	0.01566	0.1305	0.0261	0.001362
cas	1	3	0	0	1.3	0.32	1.7	0.3	0.28	3.3	0.0429	0.01056	0.0561	0.0099	0.000348
hoj	1	4	0	0	2.78	0.22	1.6	0.27	0.19	9.4	0.26132	0.02068	0.1504	0.02538	0.001944
cas	1	4	0	0	0.97	0.21	1.9	0.28	0.19	2.9	0.02813	[illegible]	0.0551	0.00812	0.000177
hoj	2	1	0	0	2.63	0.21	1	0.4	0.27	4.2	0.11046	0.00882	0.042	0.0168	0.00037
cas	2	1	0	0	0.84	0.16	0.7	0.39	0.22	3.7	0.03108	0.00592	0.0259	0.01443	0.000219
hoj	2	2	0	0	2.56	0.19	0.7	0.54	0.28	4.2	0.10752	0.00798	0.0294	0.02268	0.000335
cas	2	2	0	0	0.77	0.12	0.4	0.31	0.2	3.8	0.02926	0.00456	0.0152	0.01178	0.000173
hoj	2	3	0	0	3.41	0.24	0.6	0.54	0.37	3.2	0.10912	0.00768	0.0192	0.01728	0.000246
cas	2	3	0	0	1.26	0.24	0.9	0.34	0.27	1.8	0.02268	0.00432	0.0162	0.00612	7.78E-05
hoj	2	4	0	0	3.11	0.23	1.2	0.37	0.24	7	0.2177	0.0161	0.084	0.0259	0.001127
cas	2	4	0	0	0.96	0.19	1.6	0.29	0.17	3.3	0.03168	0.00627	0.0528	0.00957	0.000207
hoj	1	1	0	1	3.17	0.21	1.7	0.38	0.24	6.5	0.20605	0.01365	0.1105	0.0247	0.000887
cas	1	1	0	1	0.89	0.16	1.9	0.39	0.17	1.3	0.01157	0.00208	0.0247	0.00507	2.7E-05
hoj	1	2	0	1	2.51	0.2	2	0.28	0.19	5.7	0.14307	0.0114	0.114	0.01596	0.00065
cas	1	2	0	1	1.03	0.26	2.1	0.4	0.27	1.5	0.01545	0.0039	0.0315	0.006	5.85E-05
hoj	1	3	0	1	2.57	0.25	2.2	0.22	0.19	4.3	0.11051	0.01075	0.0946	0.00946	0.000462
cas	1	3	0	1	1.34	0.29	2.8	0.29	0.24	1.8	0.02412	0.00522	0.0504	0.00522	9.4E-05
hoj	1	4	0	1	3.66	0.21	1.8	0.21	0.19	4.1	0.15006	0.00861	0.0738	0.00861	0.000353
cas	1	4	0	1	1.09	0.19	1.3	0.3	0.16	1.8	0.01962	0.00342	0.0234	0.0054	6.16E-05
hoj	2	1	0	1	2.08	0.21	1.4	0.3	0.21	7.8	0.16224	0.01638	0.1092	0.0234	0.001278
cas	2	1	0	1	1.14	0.2	2	0.33	0.24	3.9	0.04446	0.0078	0.078	0.01287	0.000304
hoj	2	2	0	1	3.28	0.21	0.7	0.36	0.24	4.7	0.15416	0.00987	0.0329	0.01692	0.000464
cas	2	2	0	1	0.9	0.19	0.7	0.42	0.21	1.3	0.0117	0.00247	0.0091	0.00546	3.21E-05
hoj	2	3	0	1	2.66	0.18	1.2	0.55	0.31	4.2	0.11172	0.00756	0.0504	0.0231	0.000318
cas	2	3	0	1	0.93	0.17	1	0.34	0.21	1.2	0.01116	0.00204	0.012	0.00408	2.45E-05
hoj	2	4	0	1	2.66	0.2	1.5	0.41	0.23	6	0.1596	0.012	0.09	0.0246	0.00072
cas	2	4	0	1	0.87	0.19	1.5	0.37	0.16	2.3	0.02001	0.00437	0.0345	0.00851	0.000101
hoj	1	1	2	1	3.06	0.21	1.3	0.3	0.23	4.4	0.13464	0.00924	0.0572	0.0132	0.000407
cas	1	1	2	1	1.21	0.21	1.7	0.22	0.18	1.7	0.02057	0.00357	0.0289	0.00374	6.07E-05
hoj	1	2	2	1	3.71	0.2	1.3	0.34	0.2	4.4	0.16324	0.0088	0.0572	0.01496	0.000387
cas	1	2	2	1	0.93	0.16	1.7	0.36	0.21	1.2	0.01116	0.00192	0.0204	0.00432	2.3E-05
hoj	1	3	2	1	2.37	0.2	1.9	0.2	0.2	4	0.0948	0.008	0.076	0.008	0.00032
cas	1	3	2	1	0.83	0.18	1.7	0.3	0.19	1.1	0.00913	0.00198	0.0187	0.0033	2.18E-05
hoj	1	4	2	1	3	0.2	1.9	0.34	0.19	6.1	0.183	0.0122	0.1159	0.02074	0.000744
cas	1	4	2	1	0.96	0.2	2	0.19	0.14	1.3	0.01248	0.0026	0.026	0.00247	3.38E-05
hoj	2	1	2	1	2.83	0.19	1.6	0.33	0.22	7	0.1981	0.0133	0.112	0.0231	0.000931
cas	2	1	2	1	0.86	0.16	1.8	0.33	0.23	2.1	0.01806	0.00336	0.0378	0.00693	7.06E-05
hoj	2	2	2	1	2.66	0.2	0.7	0.34	0.28	5.5	0.1463	0.011	0.0385	0.0187	0.000605
cas	2	2	2	1	1.17	0.19	1.2	0.25	0.21	1.8	0.02106	0.00342	0.0216	0.0045	6.16E-05
hoj	2	3	2	1	2.91	0.18	1.7	0.21	0.19	4.1	0.11931	0.00738	0.0697	0.00861	0.000303
cas	2	3	2	1	1.2	0.22	2.1	0.29	0.21	1.3	0.0156	0.00286	0.0273	0.00377	3.72E-05
hoj	2	4	2	1	2.37	0.16	1.3	0.37	0.2	6.8	0.16116	0.01088	0.0884	0.02516	0.00074
cas	2	4	2	1	0.87	0.19	1.5	0.37	0.16	1.6	0.01392	0.00304	0.024	0.00592	4.86E-05

totdm2	ntot2	ptot2	ktot2	catot2	mgtot2	N%2	P%2	K%2	Ca%2	Mg%
12.3	0.22345	0.02583	0.2296	0.0369	0.001799	1.816667	0.21	1.866667	0.3	0.014623
7.5	0.15019	0.01593	0.1088	0.02307	0.000759	2.002533	0.2124	1.450667	0.3076	0.010113
12	0.23082	0.02622	0.1866	0.036	0.001711	1.9235	0.2185	1.555	0.3	0.014257
12.3	0.28945	0.02677	0.2055	0.0335	0.002121	2.353252	0.217642	1.670732	0.272358	0.01724
7.9	0.14154	0.01474	0.0679	0.03123	0.000589	1.791646	0.186582	0.859494	0.395316	0.007462
8	0.13678	0.01254	0.0446	0.03446	0.000508	1.70975	0.15675	0.5575	0.43075	0.006356
5	0.1318	0.012	0.0354	0.0234	0.000324	2.636	0.24	0.708	0.468	0.00647
10.3	0.24938	0.02237	0.1368	0.03547	0.001334	2.421165	0.217184	1.328155	0.344369	0.012951
7.8	0.21762	0.01573	0.1352	0.02977	0.000914	2.79	0.201667	1.733333	0.381667	0.011722
7.2	0.15852	0.0153	0.1455	0.02196	0.000708	2.201667	0.2125	2.020833	0.305	0.009838
6.1	0.13463	0.01597	0.145	0.01468	0.000556	2.207049	0.261803	2.377049	0.240656	0.009118
5.9	0.16968	0.01203	0.0972	0.01401	0.000415	2.875932	0.203898	1.647458	0.237458	0.007027
11.7	0.2067	0.02418	0.1872	0.03627	0.001582	1.766667	0.206667	1.6	0.31	0.01352
6	0.16586	0.01234	0.042	0.02238	0.000496	2.764333	0.205667	0.7	0.373	0.008267
5.4	0.12288	0.0096	0.0624	0.02718	0.000342	2.275556	0.177778	1.155556	0.503333	0.006333
8.3	0.17961	0.01637	0.1245	0.03311	0.000821	2.163976	0.197229	1.5	0.398916	0.009886
6.1	0.15521	0.01281	0.0861	0.01694	0.000467	2.544426	0.21	1.411475	0.277705	0.00766
5.6	0.1744	0.01072	0.0776	0.01928	0.00041	3.114286	0.191429	1.385714	0.344286	0.007326
5.1	0.10393	0.00998	0.0947	0.0113	0.000342	2.037843	0.195686	1.856863	0.221569	0.006702
7.4	0.19548	0.0148	0.1419	0.02321	0.000778	2.641622	0.2	1.917568	0.313649	0.010514
9.1	0.21616	0.01666	0.1498	0.03003	0.001002	2.375385	0.183077	1.646154	0.33	0.011006
7.3	0.16736	0.01442	0.0601	0.0232	0.000667	2.292603	0.197534	0.823288	0.317808	0.009131
5.4	0.13491	0.01024	0.097	0.01238	0.00034	2.498333	0.18963	1.796296	0.229259	0.006292
8.4	0.17508	0.01392	0.1124	0.03108	0.000788	2.084286	0.165714	1.338095	0.37	0.009387

totdm2	ntot2	ptot2	ktot2	catot2	mgtot2	N%2	P%2	K%2	Ca%2	Mg%
12.3	0.22345	0.02583	0.2296	0.0369	0.001799	1.816667	0.21	1.866667	0.3	0.014623
7.5	0.15019	0.01593	0.1088	0.02307	0.000759	2.002533	0.2124	1.450667	0.3076	0.010113
12	0.23082	0.02622	0.1866	0.036	0.001711	1.9235	0.2185	1.555	0.3	0.014257
12.3	0.28945	0.02677	0.2055	0.0335	0.002121	2.353252	0.217642	1.670732	0.272358	0.01724
7.9	0.14154	0.01474	0.0679	0.03123	0.000589	1.791646	0.186582	0.859494	0.395316	0.007462
8	0.13678	0.01254	0.0446	0.03446	0.000508	1.70975	0.15675	0.5575	0.43075	0.006356
5	0.1318	0.012	0.0354	0.0234	0.000324	2.636	0.24	0.708	0.468	0.00647
10.3	0.24938	0.02237	0.1368	0.03547	0.001334	2.421165	0.217184	1.328155	0.344369	0.012951
7.8	0.21762	0.01573	0.1352	0.02977	0.000914	2.79	0.201667	1.733333	0.381667	0.011722
7.2	0.15852	0.0153	0.1455	0.02196	0.000708	2.201667	0.2125	2.020833	0.305	0.009838
6.1	0.13463	0.01597	0.145	0.01468	0.000556	2.207049	0.261803	2.377049	0.240656	0.009118
5.9	0.16968	0.01203	0.0972	0.01401	0.000415	2.875932	0.203898	1.647458	0.237458	0.007027
11.7	0.2067	0.02418	0.1872	0.03627	0.001582	1.766667	0.206667	1.6	0.31	0.01352
6	0.16586	0.01234	0.042	0.02238	0.000496	2.764333	0.205667	0.7	0.373	0.008267
5.4	0.12288	0.0096	0.0624	0.02718	0.000342	2.275556	0.177778	1.155556	0.503333	0.006333
8.3	0.17961	0.01637	0.1245	0.03311	0.000821	2.163976	0.197229	1.5	0.398916	0.009886
6.1	0.15521	0.01281	0.0861	0.01694	0.000467	2.544426	0.21	1.411475	0.277705	0.00766
5.6	0.1744	0.01072	0.0776	0.01928	0.00041	3.114286	0.191429	1.385714	0.344286	0.007326
5.1	0.10393	0.00998	0.0947	0.0113	0.000342	2.037843	0.195686	1.856863	0.221569	0.006702
7.4	0.19548	0.0148	0.1419	0.02321	0.000778	2.641622	0.2	1.917568	0.313649	0.010514
9.1	0.21616	0.01666	0.1498	0.03003	0.001002	2.375385	0.183077	1.646154	0.33	0.011006
7.3	0.16736	0.01442	0.0601	0.0232	0.000667	2.292603	0.197534	0.823288	0.317808	0.009131
5.4	0.13491	0.01024	0.097	0.01238	0.00034	2.498333	0.18963	1.796296	0.229259	0.006292
8.4	0.17508	0.01392	0.1124	0.03108	0.000788	2.084286	0.165714	1.338095	0.37	0.009387

APPENDIX X: Coefficients of the regression analyses.

	material	α	s.e.	β	s.e.	R^2	d.f
↑0	leaves	0.339	0.36	1.573	2.31	0.169	6
	sheaths	0.286	0.08	-0.30	0.54	0.657	6
	total	0.685	0.36	1.274	2.32	0.372	6
↑1	leaves	0.242	0.11	3.568	1.08	0.429	6
	sheaths	0.230	0.04	0.107	0.38	0.847	6
	total	0.472	0.47	3.676	1.28	0.669	6
+1	leaves	0.386	0.11	1.802	0.63	0.682	6
	sheaths	0.146	0.02	0.286	0.13	0.877	6
	total	0.533	0.12	2.087	0.67	0.779	6