

Report on Trip to Costa Rica
June 21 - 27, 1998

USAID Grant No. LAG-G-00-97-00002-00

SM-CRSP Project *Decision Aids for Integrated Nutrient Management*

Travel Team:

Nguyen Hue - University of Hawaii

Jot Smyth - North Carolina State University

Michael Waggoner - North Carolina State University

Objectives:

The peach palm production area in the Atlantic zone of Costa Rica is one of the project's three intensive testing sites, wherein developmental research to fill existing knowledge gaps in the decision support system is conducted jointly by U.S. university scientists and national institute collaborators. Unique properties of this site, relative to the sites in Mali and Philippines, include a humid tropical environment, prevalence of Andisols and a tree crop-based agricultural system. Since the initial site selection visit last year (Osmond et al., 1997), project activities focused on characterization of the physical and socio-economic conditions (Alvarado and Salas, 1998) and a baseline assessment of land use management and decision making processes by farmers, agri-business and government agencies within the region (Alvarado et al., 1998). Based on these initial site inventories, U.S. and Costa Rican scientists identified critical knowledge gaps for the integrated soil nutrient management decision support system (IntDSS) and outlined field and laboratory activities to acquire the information.

The objective of this trip was to assist Costa Rican collaborators in designing experiments and determining research protocol for field and greenhouse trials planned for year 2 of the project on the following topics:

- accumulation of aboveground biomass and nutrients in heart-of-palm plantations at different ages of establishment;
- changes in chemical properties and nutrient availability of Andisols by recycled peach palm litter pruned during heart-of-palm harvest; and
- H/Al rhizotoxicity and Ca/Mg requirements for peach palm seedling root growth in Ultisols and Andisols.

Upon learning that Ing. Elio Duron would be in Costa Rica, he was invited to participate in our discussions and field tours. Elio coordinates CIMMYT's Central American network for Maize Agronomic Trials with whom we will evaluate the IntDSS software. Elio's participation in this trip provided insights on the nature of IntDSS which should facilitate our future coordination of extensive network evaluation activities.

Itinerary:

June 21 Arrival in San José

June 22 Tour of UCR-CIA lab, greenhouse and library facilities; preliminary discussions with Alvarado, Molina, Salas, Soto and Uribe about treatments and design for each planned experiment related to nutrient management of peach palm plantations for heart-of-palm production. Elio Duron from CIMMYT/Guatemala arrives and joins us.

- June 23 Travel to DEMASA farm at Sarapiquí accompanied by Alvarado, Molina and Salas; tour of peach palm plantation operations, ongoing field research and discussions on future information needs, hosted by Mr. Herman Hidalgo; return to San José.
- June 24 Tour of agriculture production systems in the region surrounding Poas volcano; seminars describing the project's 5-year plan, recent advances in soil acidity research and techniques for assessing mineralization of organic inputs were presented by Smyth, Hue and Waggoner to the Agronomy Department faculty, students and representatives from various national institutions. Duron departs for Honduras.
- June 25 Tour of agriculture systems in extensive areas of Ultisols in San Isidro valley, oil palm production along the Pacific coast and return to San José
- June 26 Meetings with Alvarado, Molina, Salas, Soto and Uribe to finalize details on design and measurements in the planned experiments.
- June 27 Departure for the U.S.

Agronomic Characteristics of Peach Palm Plantations for Heart-of-Palm Production

Since our initial site visit last year, Ing. Eloy Molina has assembled some of the existing data on peach palm production practices within the country (Molina, 1998). These are described in the following along with his description of the current production practices in the Sarapiquí region.

- Peach palm seeds harvested from trees in the region are germinated in raised nursery beds; seedlings are grown in the nursery for an additional 2 months. Thereafter, bare-root seedlings are harvested and transplanted in the field the same day.
- Field plant density is 5000 plant ha⁻¹ spaced by 1 m within rows and 2 m between rows. Many of the older plantations still have only 3900 plants ha⁻¹.
- By the end of the 2nd year in the field each plant unit (locally called “cepa”) ideally has four stems, each with 2-3 m height, and 6-8 suckers that eventually will replace harvested stems.
- By the 2nd year stems are harvested from each field for heart-of-palm (“palmito”) every two weeks. Criteria for ‘palmito’ harvest used to be a certain stem diameter at the base, but DEMASA is now shifting to harvesting when a certain leaf number reaches 75% of maximum expansion.
- Upon harvesting a stem, in-field processing includes removing all foliage, a 5-6cm base of the stem, and peeling off the outer layer of the stem. All residues from in-field processing are left in the 2-m area between plant rows at the site of stem harvest.
- Aboveground biomass and ‘palmito’ production reaches an equilibrium when plantations are 3-4 years old. Data in Table 1 from different studies in the Atlantic zone by Jongschaap (1993) and Herrera (1989) provide snapshots of dry matter and nutrient accumulation at different ages of peach palm plantations. However time and space are confounded when comparing between the two studies. Jongschaap (1993) measured dry matter accumulation (roots, stems, leaves and rachis) between 19 and 137 days after transplanting nursery seedlings in the field at 4000 plants ha⁻¹. There was little growth during the 2 initial months

Table 1. Biomass and nutrient accumulation in peach palm plantations of different ages.

| PLANTATION AGE | PLANT COMPONENT | DRY WEIGHT | UPTAKE | | | | | | | | |
|--------------------------------|-----------------------------------|--|--|------|-----|----|----|------|-----|-----|-----|
| | | | N | P | K | Ca | Mg | Cu | Fe | Mn | Zn |
| | | kg ha ⁻¹ | ----- kg ha ⁻¹ year ⁻¹ ----- | | | | | | | | |
| 19 days | Roots, stems, | 62 | | | | | | | | | |
| 68 days | leaves and rachis [¶] | 95 | | | | | | | | | |
| 137 days | | 419 | 17 | 2.5 | 18 | | | | | | |
| | | kg ha ⁻¹ year ⁻¹ | | | | | | | | | |
| Mature plantation [§] | Residues+Plants [†] | 19500 | 503 | 33.1 | 217 | 60 | 39 | 0.16 | 1.8 | 2.2 | 0.2 |
| | Palmito [‡] | 1700 | 28 | 4.8 | 31 | 5 | 4 | 0.02 | 0.0 | 0.1 | 0.1 |
| | Sum | 21200 | 531 | 37.9 | 248 | 65 | 43 | 0.18 | 1.8 | 2.3 | 0.3 |

[¶] Replicated experiment on Andisol at Agropalmito S.A., near Guapiles; adapted from Jongschaap (1993) and based on 4000 plants ha⁻¹.

[§] Adapted from Herrera (1989) and based on 3200 plants ha⁻¹.

[†] Crop residues left in the field with each 'palmito' harvest plus standing biomass.

[‡] Palmito and outer stem sheaths exported from the field for processing.

after transplanting, but dry weight quadrupled during the succeeding 4 months. Dry matter partitioning during the 6-month study period was constant among measured plant components with mean values of 34% for roots, 32% for stems, 34% for leaves and 5% for rachis. The mature plantation studied by Herrera (1989) was estimated to have 3200 plants ha⁻¹ and produced an average of three ‘palmitos’ plant⁻¹ in a year. Relative to the total nutrient accumulation on the aboveground biomass, nutrient export in ‘palmito’ harvest is relatively small.

- During the 2-3 month dry season in the Sarapiquí region (with 50-75 mm rainfall month⁻¹) ‘palmito’ production drops by as much as 50%.
- Assessment of peach palm root distribution in a 4-year-old plantation in an Andisol by Jongschaap (1993), via the trench profile method, indicated that about 65% of the total number of roots were concentrated in the top 20 cm soil layer (Figure 1).

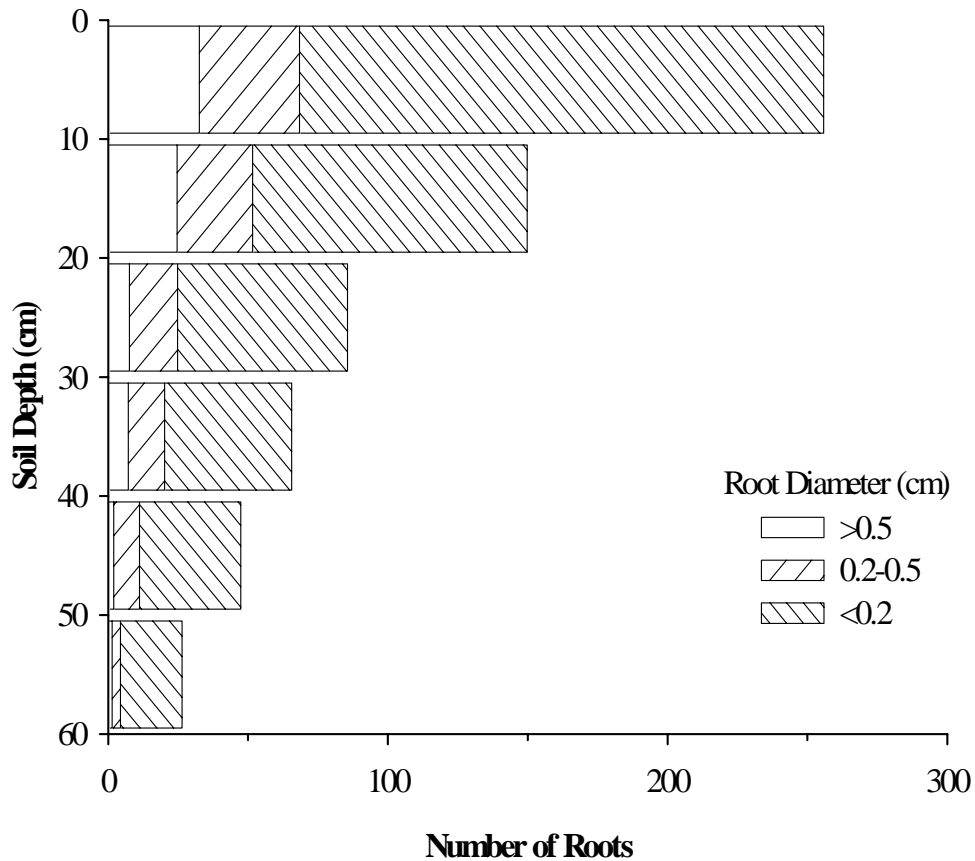


Figure 1 Peach palm root distribution within an Andisol profile (Jongschaap, 1993)

- Fertilizers are applied every 1.5 - 2 months. Alvarado and Salas (1998) indicated the following range of annual fertilization rates in the Sarapiquí region:

| NUTRIENT | kg ha⁻¹ year⁻¹ |
|-----------------|---|
| N | 200 - 400 |
| P | 22 - 44 |
| K | 50 - 125 |
| Mg | 18 - 36 |
| S | 40 - 80 |
| Calcitic lime | 500 - 2000 |

Current fertilizer recommendations are based primarily on field experience during the last 20 years, rather than actual field experiments to measure yield response.

- A compilation of 13 soil samples analyzed in UCR labs for peach palm plantations throughout the Atlantic Zone provided the following range of soil test values:

| VARIABLE | RANGE |
|--|--------------|
| pH in H ₂ O | 4.1 - 6.0 |
| Exchangeable Ca [¶] (cmol L ⁻¹) | 1.1 - 8.5 |
| Exchangeable Mg [¶] (cmol L ⁻¹) | 0.2 - 2.3 |
| Exchangeable K [§] (cmol L ⁻¹) | 0.1 - 0.6 |
| Exchangeable Al [¶] (cmol L ⁻¹) | 0.2 - 4.4 |
| Al saturation (%) | 2 - 71 |
| Extractable P [§] (mg L ⁻¹) | 4 - 34 |
| Extractable Cu [§] (mg L ⁻¹) | 5 - 36 |
| Extractable Fe [§] (mg L ⁻¹) | 74 - 2098 |
| Extractable Mn [§] (mg L ⁻¹) | 2 - 94 |
| Extractable Zn [§] (mg L ⁻¹) | 0.7 - 10.1 |

[¶] 1.0 N KCl extraction.

[§] Hunter's Modified Olsen solution.

- The range of nutrient concentrations for peach palm leaf samples analyzed by UCR labs is as follows:

| NUTRIENT | RANGE |
|---------------------------|--------------|
| N (%) | 2.5 - 4.0 |
| P (%) | 0.15 - 0.30 |
| Ca (%) | 0.2 - 0.5 |
| Mg (%) | 0.2 - 0.3 |
| K (%) | 0.8 - 1.5 |
| Cu (mg kg ⁻¹) | 8 - 15 |
| Fe (mg kg ⁻¹) | 100 - 200 |
| Mn (mg kg ⁻¹) | 50 - 200 |
| Zn (mg kg ⁻¹) | 15 - 25 |

Visit to the DEMASA Plantation

We were greeted at the plantation by Ing. Herman Hidalgo, who coordinates agronomic research on peach palm for this company. Herman has been working for DEMASA for about 4 months, having recently completed his M.Sc. in Plant Pathology at N.C. State University under the guidance of Dr. Sutton. Herman gave us a tour of all field operations, including demonstrations on the ‘palmito’ harvest process.

On this farm there are several adjoining fields reserved for research activities. Plantations in these fields are between 10 and 15 years. Prior to our arrival UCR-CIA and DEMASA had designed and established a lime - gypsum experiment (see attached description of experiments). Each treatment replicate contains 100 plants in 5 adjacent rows. DEMASA provides lime and fertilizers, and field labor for harvesting, soil sampling and plant sampling; UCR-CIA assists in field monitoring of the experiments and provides soil testing and plant analysis. Discussions were underway between UCR-CIA and DEMASA to design an experiment to evaluate yield response to fertilizer P. Both parties were receptive to our suggestions on this experiment, to provide information needed for IntDSS. Our suggestions focused on determining fertilizer P treatments based on a P buffer coefficient derived from laboratory incubation of soil from the targeted site with increasing levels of added P (see attached description of experiments). Plans are also underway to eventually install experiments to evaluate yield response to fertilizer N and K.

Soil sampling on experiments currently are taken at 15-cm increment depths. On the next scheduled soil sampling date, samples for the 0-15cm depth will also be taken in three 5-cm increments to compare soil test results. Given the pH-dependent nature of soil charge, the surface application of lime and fertilizers, and the significant amount of crop residues continuously deposited on the soil surface, it is quite possible that soil chemical properties for the surface 5-cm layer are markedly different from the underlying 10cm of soil.

Collaboration between UCR-CIA and DEMASA is very good. Herman was very receptive to our planned activities on peach palm during the second year of the project. DEMASA is willing to construct a covered area with transparent plastic for some of the short-term experiments that will be conducted in pots. For some of the field experiments involving plantations of different ages, they see no problem in obtaining access to adjacent farmer fields from which they purchase 'palmito' for their canning factory.

Planned Field and Laboratory Activities for Project Year 2

Considerable time was devoted to discussing planned activities, designing experiments, and outlining field and laboratory protocols. A description of each experiment and responsible investigators is attached to this report.

Laboratory investigations with peach palm residues pruned during 'palmito' harvest seek to determine if soluble organics produced during mineralization of these residues have a potential liming effect and, if so, estimate the CaCO₃ equivalence of this effect via a bio-assay. These studies are complemented by a pot trial to evaluate the extent to which peach palm root growth responds to amelioration of exchangeable Al and increased soil Ca or Mg supply.

Field experiments on biomass and nutrient accumulation with plantation age will provide baseline data for determining peach palm nutrient requirements, constructing nutrient input-output balance sheets, and devising strategies to improve soil nutrient management practices during the continuum from plantation establishment to maturity. The complimentary field experiment to assess residue decomposition and nutrient release will provide indications on potential nutrient re-cycling within the existing management practices. Nutrient movement monitored through field lysimeter batteries will be useful in predicting nutrient losses from the system and in predicting lime-derived movement of Ca and Mg into subsoils.

The lime-gypsum and P fertilization trials will be conducted over several years. These trials will provide information on both immediate and residual effects of lime and P, plus validation of some laboratory results and current methods for short-term estimation of P fertilizer requirements.

Reports and Literature Cited:

Note - names listed in parentheses for reports correspond hyperlink names to the Acrobat Reader files which can be downloaded from the project's Web site located at the following address:

<http://intdss.soil.ncsu.edu/sm-crsp/Download/Download.htm>

Alvarado, A. and R. Salas. 1998. Land use management and policy in Central America with special reference to the Atlantic zone of Costa Rica. pp.4-14. *In* Smyth, T.J. (ed.) Summary report of the program planning workshop: decision aids for integrated soil nutrient management project. Soil Management CRSP, 1-3 December, 1997, Honolulu, HI. (*Project planning workshop*)

Alvarado, A., F.J. Smith and T.J. Smyth. 1998. Baseline study of land use management and decision making processes with a focus on non-traditional crops, small farmers, agro-industry, and development policy in Costa Rica. Decision Aids for Integrated Soil Nutrient Management Project, Soil Management CRSP. 16p. (*Baseline survey report/Costa Rica*)

Herrera, W. 1989. Fertilización del pejobaye para palmito. Serie Técnica Pejobaye. Boletín Informativo 1(2):5-10. University of Costa Rica, San José.

Jongschaap, R. 1993. Palmito (*Bactris gasipaes* H.B.K.) growth and management in the humid lowlands of the Atlantic zone of Costa Rica. Atlantic Zone Programme Report no. 60 (Field Report no. 107). Agric. Univ. Wageningen, CATIE and Minsiterio de Agricultura y Ganaderia (MAG), Costa Rica. 52p.

Molina, E. 1998. Fertilizacion de pejibaye para palmito. Centro de Investigaciones Agronómicas, University of Costa Rica, San José. 26p.

Osmond, D., S. Reid, M. Robotham, F. Smith, J. Smyth and R. Yost. 1997. Report on trip to Costa Rica. July 13-19, 1997. USAID Grant No. LAG-G-00-97-00002-00. SM-CRSP IntDSS Project. 8p.(*Trip reports: Costa Rica, July 13-19, 1997*)

List of Contacts:

UCR-CIA, San José

Dr. Alfredo Alvarado, Soil Scientist and Director

Dr. Rafael Mata, Soil Scientist

Dr. Elemer Bornemisza, Soil Scientist

Ing. Gabriela Soto, Soil Ecologist

Ing. Eloy Molina, Soil Scientist and Soil & Plant Analysis Lab Supervisor

Ing. Lidieth Uribe, Soil Scientist

Ing. Floria Bertsch, Soil Scientist

DEMASA, Sarapiquí, Heredia

Ing. Herman Hidalgo, Plant Pathologist and Research Coordinator

CIMMYT/Guatemala

Ing. Elio Duron, Coordinator for the Central American Maize Agronomic Trials Network

Experimental Design and Research Protocol for Experiments

Effect of Mulch from Peach Palm Prunings on Soil Chemical Properties

Principal Investigators:

UCR - Lidieth Uribe and Rafael Salas

U.S. - Nguyen Hue and Jot Smyth

Location: UCR-CIA laboratories

Soil: Andisol from the DEMASA farm.

Prunings: plant material used in this experiment should be the prunings left in the field as residues upon the harvest of heart-of-palm.

Bioassay Plant: Use an acidity-sensitive bean variety, on the four 10-cm soil segments of the 10 to 40 cm column depth.

Number of Replicates: 4

Treatments:

- a. Control, with no plant material added.
- b. Lime (CaCO_3) at 2 tons/ha added to the surface
- c. Prunings at 10 tons/ha added to the surface
- d. CaCO_3 at 2 ton/ha mixed with prunings at 10 tons/ha and added to the surface

Column set up. See drawing.

Mulch properties: Peach palm prunings should be ground and screened to pass 2 mm sieve (no. 10 mesh). Moisten the pruning with deionized water, place on the surface of the soil column for 1 to 2 weeks before leaching.

Column Leaching: Add approximately 40 cm of deionized water in 5 days (that is, 8 cm water per day). Water should be added at a rate of 4 cm per hour.

Post-Leaching Soil Subdivision: After leaching, open the soil column, discard the top and bottom 2.5 cm of soil. The remaining 40-cm soil depth should be cut into four equal segments of 10 cm each.

Soil Analysis: On each of the four soil segments measure soil pH (1:1 water), exchangeable Al, Ca, Mg, extractable K and water soluble carbon.

Leachate Analysis: Measure pH, EC, Al, Ca, Mg, K and soluble C of the leachate.

Root Length Bioassay: On the remaining soil of each of the four 10-cm soil segments conduct a bioassay, using an acidity-sensitive bean variety. One pre-germinated bean seedling, from a group of seedlings selected to have uniform length of radicles, is planted to cups containing moistened soil from a 10-cm soil segment. After about 6 days of growth the cups are split open and length of the bean taproot is measured.

Evaluation: results on exchangeable cation distribution and bean root elongation with depth in the soil column, and leachate characteristics for each treatment are evaluated to determine potential mechanisms associated with cation movement in the Andisol under peach palm residue. Possible new experiments may be developed, depending on the outcomes of the initial study.

Liming Equivalence of Peach-Palm Prunings Applied as a Mulch

Principal Investigators:

UCR - Lidieth Uribe, Alfredo Alvarado, Rafael Salas

U.S. - Nguyen Hue, Jot Smyth

Location: UCR-CIA laboratory/greenhouse facilities

Replications: four

Pots: pots or PVC pipe with at least 20 cm of soil depth

Soils: Andisol and Ultisol from DEMASA region

Constructing a Lime Response Curve for Each Soil :

1. CaCO_3 rates: 0, 0.25, 0.50, 1.0 and 1.5 times the equivalents of soil exchangeable Al.
2. Treatment setup: Mix lime with the soil thoroughly; moisten the soils to field capacity, and incubate for at least 2 weeks before planting.

Preparing Soil Treatments with Mulch of Peach Palm Prunings:

1. Prunings must be air dried and ground to pass a 2-mm sieve.
2. Apply the material to the soil surface at 0, 2.5, 5.0, and 10.0 g/kg soil. Moisten to field capacity and incubate for at least 2 weeks before seeding.

Plant Root Growth:

1. An acid sensitive bean or sorghum species. Use about 8 seeds per replication of each treatment.
2. After 3 to 4 weeks of plant growth measure aboveground biomass and weight and length of roots in each pot.

Basal Fertilizers:

Add enough N, P, K to support seedling growth for 4 weeks. Suggested rates are 100 ppm N, P and K.

Peach Palm Root Elongation Response to Lime, Ca and Mg

Principal Investigators:

UCR - Rafael Salas and Lidieth Uribe

DEMASA - Herman Hidalgo

U.S. - Jot Smyth and Nguyen Hue

Purpose: evaluation of which components of the soil acidity syndrome might serve as a constraint to peach palm root growth.

Treatments:

2 soils - Andisol and Ultisol

7 soil treatments -

- a. Control
- b. CaCO_3 at 1X the soil exchangeable Al
- c. Either MgCO_3 or MgO at 1X the soil exchangeable Al
- d. A 50:50% mixture of $\text{Ca}(\text{NO}_3)_2$ and CaCl_2 to supply Ca in amounts equivalent to the Ca supplied as CaCO_3
- e. CaSO_4 with Ca supplied in amounts equal to the CaCO_3 treatment
- f. MgSO_4 with Mg supplied in equivalent amounts to the MgCO_3 or MgO treatment
- g. A 50:50% mixture of CaCO_3 and MgCO_3 or MgO on a lime equivalence basis to total 1.0X the soil exchangeable Al.

Replications: six

Location: clear-plastic covered field house at the DEMASA farm

Plants per pot: 1 pre-germinated seedling grown to a maximum of no more than 5 months.

Other Nutrients: Once initial soil analysis is done for pH, Ca, Mg, K, Al, and P these will be provided to Smyth and Hue and some discussion with Salas and Uribe to define the other nutrient additions. This can be done via e-mail. The primary concern is the level of basal nutrients and avoidance of Ca/Mg imbalances in soils with >2 cmol of exchangeable Al (i.e. leading to high amounts of Ca, Mg or nitrates).

Root Length Measures at Harvest:

All roots will be washed free of soil using a sieve with mesh size similar to that used to separate sand and silt fractions. Roots will be stored under refrigeration in a alcohol solution until length is measured with a desktop scanner and the "RootLaw" software.

Number of Harvests and Number of Soils: it would be desirable to have at least the two major soil types in the DEMASA region. Other soils could include the Ultisol from San Isidro or others of local interest.

If desired locally, number of harvest could be increased by adding more pots and replicates to harvest roots at 1 and 3 as well as 5 months. However, this will double or triple the size of the experiment.

Biomass and Nutrient Accumulation with Time of Peach Palm Plantation Establishment

Principal Investigators:

UCR - Rafael Salas and Eloy Molina

DEMASA - Herman Hidalgo

U.S. - Jot Smyth, Mike Waggoner and Nguyen Hue

Location: DEMASA and adjacent farms

Plantation Ages: 2, 4, 8, and 16 years

Desirable Plantation Characteristics: each on a similar soil type, under similar management practices and similar climatic regime

Sampling Units: all plants in 10 continuous meters of a single peach palm row

Replications of sampling units in each plantation age: 6 units in the same field, blocked according to observed gradients in plant characteristics, soil properties and/or landscape position. Each replicate should be separated from surrounding replicates in the same field by a minimum of 4 meters distance. Prior to defining sampling units, soil in each field should be sampled on a uniform grid at 0-5, 5-10, 10-15, 15-30, 30-60 and 60-90cm depths for routine soil test analysis to assess gradients within fields of chemical soil properties (for replicate distribution).

Plant Sampling Protocol:

1. Determine total number of cepas and plant shoots (suckers) per cepa in each sampling unit;
2. Sampling frequency - once every month for 12 consecutive months
3. Sample - at each sampling date, the aboveground portion of each shoot that would be routinely harvested for palmito processing; record for each 10-m sampling unit the number of stems harvested and their fresh weight on each sampling date (note: on some dates, there may be no harvest if none of the shoots are at the appropriate stage of development for commercial harvest).
4. On all the other harvest dates conducted by DEMASA on two-week intervals, record the number of stems which are harvested from each 10-m sampling unit.
5. Sample components:
 - a. Minimum desired: subdivide the shoot into two parts - (1) that which is removed from the field for the packing plant, and (2) that which remains in the field as residue.
 - b. Optional additional subdivision of the sample: leaves, midrib, basal section of stem, top section of stem, and stem peelings.
 - c. *Subdivision of the harvested shoot into components, **beyond the desired minimum**, should be determined based on UCR and DEMASA interests in the level of information desired. **However**, sample subdivision should be uniform across replicates, fields and sampling dates once it is defined.*
6. Fresh weight measurements: fresh weights can be determined by combining each sample component of **all harvested plant shoots** in each 10-m replicate, **but** note under item 7 that follows that the subsample for moisture and nutrient content determination should consist of all sample components for one harvested plant shoot in each 10-m replicate.
7. Subsample for determination of moisture content and nutrient content: **all plant components of at least one harvested plant shoot in each replicate, field and harvest date** (this will ensure that we maintain proportional representation among plant components in the subsample).

8. Nutrient analysis: grind the entire subsample taken for moisture determination **by each of the plant components chosen in the sampling protocol**. On a homogenous subsample of ground material for each plant component analyze a sub-subsample for N, P, K, Ca, Mg, Al, S, Fe, Cu, Mn and Zn.
9. Final sampling date (number 12): sample the stems routinely harvested at this date for peach palm following the protocol described above; then sample aboveground components of all remaining plant shoots in the 10-m row length of each sampling unit.
10. Productivity of peach and quality of heart of palm: should be evaluated in cepas outside the sampling areas, according to DEMASA standards.

Soil Sampling Protocol:

1. Minimum desired: for each 10-m sampling unit composite samples by 0-5, 10-15 and 15-30cm for routine soil test analysis and KCl extractable NO_3 and NH_4 , total N, organic C and water-soluble C. The actual sampling depth intervals may be fewer and will be based on results obtained in the initial sampling of soils at various depths to delineate distribution of replicates in each field (see description above).
2. Frequency of sampling: prior to sampling date 1, sample date 6 and sample date 12.

Installation and Monitoring of Field Suction Lysimeters:

Principal Investigators:

UCR - Rafael Salas and Eloy Molina

DEMASA - Herman Hidalgo

U.S. - Nguyen Hue, David Bouldin and Jot Smyth

Methods: These will be installed in some of the 10-m sampling plots. There will be several replicates with a series of depths (5, 15, 30 and 60cm). Samples will be collected periodically throughout the year and analyzed for pH, EC, cations, anions and water soluble C. This will provide valuable baseline information on solute flow to complement exchangeable cation distribution in the soil profile.

Residue Decomposition - Nutrient Release Experiment

Principal Investigators:

UCR: Gabriela Soto and Lidieth Uribe

DEMASA: Herman Hidalgo

U.S.: Michael Waggoner

Location: DEMASA farm

Plantation Age: 16 years

Desirable Plantation Characteristics: the same field as used in the dry matter and nutrient accumulation experiment.

Treatments: 1 placement date in the dry season and 2 placement dates in the wet season (July and end of August).

Sampling Times: 1, 2, 4, 8, 16, 24, 32, 40, 48 weeks after litter bag placement in the field.

Replicates: 4 (for a total number of 108 bags)

Bag Size: tentatively 60 x 45 cm. The final size will be decided based on how well the plant material fits in the bag while maintaining the same physical characteristics as the litter left in the field following each commercial harvest.

Litter Bag Placement: The bags will be located between plants in the 2-m intrarow area.

Variables to Measure:

3. Initial moisture content of the plant material to go in the bags (10 samples) and also total N, P, K, Ca, Mg, carbon, cellulose, hemicellulose, lignin and polyphenols. The latter four constituents may need to be analyzed at NCSU campus facilities.
2. At each sampling time, dry weight, % soil contamination and N, P, K, Ca, Mg.

Statistical Analysis: Non-linear regression equations for % original dry weight and nutrient content remaining at each retrieval date will be determined by fitting the data to one- and two-pool models using the NLIN procedure in SAS.

Lime and Gypsum Experiment - Established Plantation

Principal Investigators:

UCR - Eloy Molina and Rafael Salas

DEMASA - Herman Hidalgo

U.S. - Jot Smyth and Nguyen Hue

Location: a 16-year-old field on the DEMASA farm

Treatments:

No lime

2 & 4 t CaCO_3 , 1 t CaCO_3 + 1 t dolomite, & 1.5 t CaCO_3 + 0.5 t dolomite

1 t gypsum

2 t CaCO_3 + 0.5, 1 and 1.5 t gypsum

All other nutrients will be applied at routine levels used by DEMASA

Plot Size and Replicates:

All treatments have 3 reps. Each rep has 5 rows of approximately 100m length; lime and gypsum was distributed near the base of cepas on both sides of each plant, but on an area basis.

Measurements:

4. Soil at both 0-15, 15-30 and 30-45 cm as well as (at least for initial samples) 0-5, 5-10 and 10-15cm.
2. Soil analyses include routine soil test
3. Heart of palm yield and quality will be measured over time using DEMASA's protocol for harvesting mature shoots on each row every two weeks during the year.

Fertilizer P Response of an Established Peach Palm Plantation

Principal Investigators:

UCR - Eloy Molina and Rafael Salas

DEMASA - Herman Hidalgo

U.S. - Jot Smyth, Nguyen Hue, Fred Cox and Russ Yost

Location: a 16-year-old field on the DEMASA farm

Plot Size and Replicates: same as for the lime/gypsum experiment, in a field with 5ppm Mod. Olsen P in 0-15cm soil depth.

Laboratory Incubation of Soil from Field with a Series of P levels: this is intended to indicate the soil P buffer coefficient (kg P required to raise the soil test P level by one ppm). This relation may vary with soil test P level in either a linear or curvilinear form.

1. To a series of soil subsamples add increasing levels of solution P concentration such that all samples reach a moisture content approaching field capacity.
2. Allow the soil to air dry; re-wet with water stir up the mixture and allow the soil to air-dry again.
3. Determine Mod. Olsen (Hunter method) and Mehlich-3 soil extractable P on each subsample and plot added P vs. soil test P.

Fertilizer P rates for the experiment:

1. Based on current experiences at DEMASA, determine what is the best estimate of the critical soil test P level for peach palm in this soil (Eloy's written summary of existing data suggests 10 ppm as the critical level).
2. Designate the critical P level as "X"
3. Select other P levels for the field experiment as follows: 0, 0.50, 0.75 and 2.00 X. If using 10 ppm as the critical level, for example, the other P rates would be 0, 5, 7.5 and 20 ppm Mod. Olsen P (note: since the field already has a soil test P level of 5 ppm, these levels will have to be adjusted to something like 5, 6, 8, 10 and 20 ppm; with time, however, these soil test P levels would decline to the desirable range - assuming the experiment is continued long enough without additional fertilizer P inputs).
4. Once the P treatments are defined in Mod. Olsen P units, convert them to kg P/ha of fertilizer P.

Fertilizer application: will be broadcast-applied to the central 1-m area between rows of plants.

Soil Sampling: about 1 week after P was applied (to allow fertilizer P solubilization) and at periodic intervals thereafter. Reason - to (a) follow residual soil test P dynamics and (b) have different soil sampling dates that could be correlated with crop yield. Minimal depths would be two: 0-5 and 0-15cm (to compare which might correlate best with yield response).

Extractable P from the initial soil sample could be used to construct a field-based relation between fertilizer P added and soil test P. This could be compared with the relation developed via laboratory incubation.

UCR is interested in compiling soil test data for both the Mod. Olsen and Mehlich 3 extractants. It is desirable that soil samples from this experiment be archived for future analysis by other methods, to be determined once Cox and UCR collaborators begin lab studies to test short-term predictions of soil P buffer coefficients.

Plant Sampling: flag leaves (the most recently and fully developed compound leaf) at frequent intervals throughout the year for P analysis and eventual correlation with yield response and soil test P. Crop yields will be measured as in the lime/gypsum experiment.