Improving Efficiency in Calcium Acquisition and Utilization by Forage Grasses and Legumes

A Proposal for: Der Bundesminister für Wirtschaftliche Zusammenarbeit (BMZ)

Executing Agency:

CIAT
International Center for Tropical Agriculture
Centro Internacional de Agricultura Tropical

laborating tner:

- University of Hohenheim, Stuttgart, Germany

January 1995

IMPROVING EFFICIENCY IN CALCIUM ACQUISITION AND UTILIZATION BY FORAGE GRASSES AND LEGUMES

Special Project Funding

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Collaborating Partner:

- Institute of Plant Nutrition, University of Hohenheim, Stugart, Germany

January 1995

Centro Internacional de Agricultura Tropical CIAT

PDO-L003

January 5, 1995

Dr. J. de Haas
Head, Agriculture and Rural Development Division
Federal Ministry for Economic Cooperation and Development (BMZ)
Friedrich-Ebert-Allee 114-116
D-53113 Bonn
Federal Republic of Germany

Ref.: ***Proposals for Special Projects***

Dear Dr. Haas:

We are pleased to identify for your consideration three special projects involving cooperation between CIAT, German partners and NARS:

(1) ***Sustainable Animal Production for the Agropastoral Systems of the Brazilian Cerrados***

This proposal was submitted in August 1994 and the peer review committee considered it to be in principle worthwhile for funding. We have revised the proposal and have addressed the three issues raised in your previous letter. As per your instructions, we have forwarded copies of the revised proposal directly to ATSAF and GTZ.

(2) ***Dynamics and Sustainability of Farming and Regional Systems in the South American Savannas***

This proposal was submitted in August 1994, but arrived too late to be considered during the last Special Project Competition. We would appreciate if it would be now considered for the current competition. We understand from the BMZ fax of December 21, 1994 that there is no need to submit additional copies of the proposal at this stage since there have been no changes to the document submitted last August.

File: PDO 3.19.1

Mailing address. Apdo. aéreo 6713. CALI. COLOMBIA. Telex 05769 CIAT CO. ITT Dialcom ID 57:CGI301 FAX 57-23-647243. Tel. 57-23-675050

(3) ***Improving Efficiency in Calcium Acquisition and Utilization by Forage Grasses and Legumes***

Copies of this proposal have been forwarded directly to ATSAF and GTZ.

We look forward to continued support for our research cooperation with German universities and NARS and we would like to thank you for consideration of our new requests.

Yours sincerely,

ROBERT D. HAVENER
Interim Director General

Attachments

cc: Dr. E. Kurschner, ATSAF
Dr. J. Friedrichsen, Head of Division, Plant Production, Plant Protection and Agricultural Research, GTZ

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Acronyms

BMZ	Der Bundesminister für Wirtschaftliche Zusammenarbeit, Germany (Federal Ministry of Technical Cooperation)
CIAT	Centro Internacional de Agricultura Tropical, Cali, Colombia (International Center for Tropical Agriculture)
GTZ	Gesselschaft für Technische Zusammenarbeit, Germany (German Agency for Technical Cooperation)
NARS	National Agricultural Research Systems
RIEPT	Red Internacional de Evaluación de Pastos Tropicales (International Network for Evaluation of Tropical Pastures)

1.0 Summary

Title: *Improving Efficiency in Calcium Acquisition and Utilization by Forage Grasses and Legumes*

Short Title: *Calcium Nutrition of Tropical Forages*

Objective of Research:

To identify plant attributes that contribute to improved efficiency in acquisition and utilization of calcium in *Brachiaria* and *Arachis* species in order to develop screening procedures to evaluate forage germplasm for efficiency in calcium acquisition and utilization.

Abstract:

The goal of the Tropical Forages Program at CIAT is to develop forage components for farming systems on acid infertile soils of the humid and sub-humid tropics which will contribute to increased and more efficient meat and milk production, soil improvement and erosion and weed control.

Inadequate nutrition is the main constraint in ruminant productivity throughout most tropical regions. Development of improved forage systems of high nutritive value is the key to increased and sustainable livestock productivity. Forage species can improve soil fertility, physical structure, and biological activity, protect soil against erosion, reduce the need for herbicide used in weed control and sequester large amounts of carbon deep in the soil, thus contributing to minimizing the greenhouse effect of increasing atmospheric CO_2.

In low fertility acid soils of the tropics, root growth (and particularly root penetration into subsoils) is limited by the availability of calcium. Forage species differ in both requirement in calcium supply to the roots and calcium demand per unit tissue weight. Inter-and intraspecific differences in calcium efficiency may be related to a higher efficiency in utilization within the plant, or a higher efficiency in acquisition of calcium by the roots. Furthermore, intracellular compartmentation and concentration of calcium in forage tissue affects feed value and animal intake.

The proposed research to be carried out in Colombia and Germany will test two hypotheses: (i) inter- and intraspecific differences in calcium acquisition are related to their root architecture, cation exchange capacity and binding of calcium to root cell walls; and (ii) lower concentrations of calcium in the shoot dry matter results in lower forage quality. Results from this research will help to identify plant attributes that contribute to greater acquisition and utilization of calcium in forages. Identification of plant attributes will contribute to the development of prototype screening procedures for tropical forage evaluation/improvement.

Cooperating Partners:

(1) Tropical Forages Program, Centro Internacional de Agricultura Tropical (CIAT), Cali, Colombia

(2) Institute of Plant Nutrition, University of Hohenheim, Stuttgart, Germany

Names of Principal Scientists:

CIAT

- Dr. I. M. Rao, Project Leader
- Dr. C. E. Lascano
- Dr. J. W. Miles
- Dr. P. C. Kerridge

University of Hohenheim

- Prof. H. Marschner, Project Co-leader

Staff to be Financed:

University of Hohenheim

- 1 doctoral student (3 years)

CIAT

- 1 technician (2 years)
- 1 field worker (3 years)

Budget Total and Breakdown by Activities and Year (Current US$):

The total budget is US$250,520, broken down as follows:

Budget	*Year 1*	*Year 2*	*Year 3*	*Total*
CIAT				
Personnel	19,000	20,100	8,000	47,100
Research and Operations	18,000	18,000	4,000	40,000
Training and Workshops	1,000	1,000	3,000	5,000
Indirect costs (20%)	7,600	7,820	3,000	18,420
Total CIAT	*45,600*	*46,920*	*18,000*	*110,520*
Hohenheim University				
Personnel	30,000	30,000	30,000	90,000
Research and Operations	2,000	10,000	14,000	26,000
Travel	10,500	8,000	5,500	24,000
Total Hohenheim Univ.	*42,500*	*48,000*	*49,500*	*140,000*
Grand Total All Partners	***88,100***	***94,920***	***67,500***	***250,520***

2.0 Background and Justification

2.1 Introduction

Forage Plants in the tropics have a major role in contributing to more sustainable agricultural systems

The availability and, particularly, the quality of feed is the main constraint to increased and more efficient animal production in the tropics of Latin America, Asia and Africa. Forage grasses and legumes can play a role in alleviating this feed shortage in the majority of production systems (Kerridge, 1994). Further it has been demonstrated that they have a major role in contributing to more sustainable agricultural systems (Vera et al., 1992). The combination of nitrogen fixing forage legumes with deep-rooted grass can increase nutrient cycling, greatly improve animal production, markedly increase soil biological activity, and store significant amounts of organic carbon deep in the soil (Thomas et al., 1994; Rao et al., 1994; Fisher et al., 1994).

Widespread adoption of forage cultivars depends on their efficient acquisition of nutrients from marginal lands

Low nutrient supply is a major limitation of forage adaptation and production in acid soils of the tropics. The use of forages adapted to low fertility acid soils is one of the most effective means of managing these soils. Considerable achievements have been made in identifying legumes and grasses well adapted to these soils but little is known about the mechanisms for adaptation (Rao et al., 1993). Widespread adoption of forage cultivars depends on efficient acquisition of nutrients from the soil and utilization for growth.

Continued progress in the selection and genetic improvement of forages will depend upon the development of rapid and reliable techniques which facilitate screening of large numbers of genotypes for tolerance to low fertility acid soils.

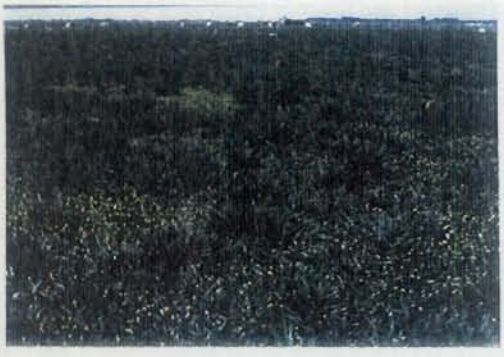
2.2 The target species

Brachiaria species are the most widely sown forages in tropical America

The genus Brachiaria is the source of a number of widely used tropical forage grasses. Together, several Brachiaria species are undoubtedly the most widely sown forages in tropical America, with 40-50 million hectares sown in Brazil alone. An important germplasm collection was assembled at CIAT and regional evaluation of this collection is essentially complete. A genetic enhancement project is in progress at CIAT which utilizes new techniques in exploiting apomixis to create synthetic gene pools with resistance to major pests (spittleburg and leaf cutter ants), high feed quality and good persistence on acid, low fertility soils.

Arachis pintoi is well-adapted to low fertility acid soils

Arachis pintoi is unique among tropical forage legumes in the humid tropics in its ability to form stable grass-legume associations with vigorous grasses like the Brachiarias. It is persistent and even increases under heavy and continuous grazing pressure. Nutritive quality is high. However, the present widely used cultivar CIAT 17434 is slow in establishment and is not tolerant of dry conditions. Research efforts are directed towards increasing the range of adaptation.



2.3 The problem

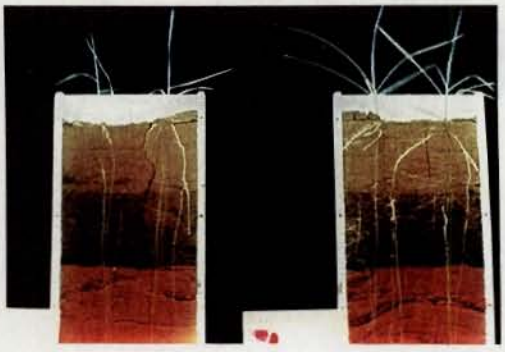
In highly weathered tropical soils, calcium content in the subsoils is often very low

In many tropical soils, low calcium (Ca) may be a greater limitation to plant growth than high aluminum (Al) but has received much less attention. In highly weathered tropical soils (Oxisols and Ultisols), plant growth is often limited by Al toxicity and phosphorus and Ca deficiency (Marschner, 1991). In the subsoil, the Ca content is often very low. Many subsoils have less than 4 mg Ca kg^{-1} of soil (Ritchey et al., 1987). Because Ca is not mobile in the phloem it does not move downwards in the roots towards the root tips where it is required for growth (Hanson, 1984). Thus, apical root zones (root tips) have to cover their Ca demand for growth by direct uptake from their immediate environment. In acid mineral soils, root growth is therefore often severely limited, particularly root penetration into the subsoil (Pearson et

al., 1973) and, correspondingly, utilization of nutrients and water from the subsoil (Howard and Adams, 1965). Low Ca activity in the subsoil may be a greater limitation to plant growth than high Al (Bruce et al., 1988).

An important aspect of calcium nutrition of tropical forages is the effect of calcium concentration on forage quality

Another very important aspect of Ca nutrition is the effect of Ca concentration on feed value and animal intake. Calcium fed as a supplement is not as effective as higher Ca in the plant tissue in improving forage quality (Minson, 1990). Therefore we need to identify forage species and ecotypes that can grow and efficiently acquire Ca from soils very low in the nutrient.



Calcium nutrition is different to other nutrients (Marschner, 1974). Because of its phloem-immobility there is no re-distribution of Ca. In root to shoot transport and distribution within the shoot, Ca is confined to the xylem and, thus, is closely related to the transpiration stream. The Ca transport into low transpiring tissues such as shoot apices and young leaves is therefore low. In addition, Ca binding to pectates in cell walls or precipitation as oxalate along the transport pathway further limit Ca supply to the sites of demand for growth. Furthermore, the common route for recycling nutrients in the phloem from mature leaves to new growth is not available for Ca (Ho and Adams, 1989). In vigorous growing tropical forage grasses and legumes, unless the import of Ca via xylem matches the demand during the accelerated expansion growth for new leaves, plant growth will be limited by Ca supply. Recent field experiments with tropical forage grasses (*Brachiaria* species) on Oxisols in Carimagua (Colombia) support this view of Ca limitation. Increase in shoot dry matter production was similar with Ca application in form of lime or gypsum, although soil pH was only increased with lime (K. Haussler, unpublished results).

Plant species differ in their ability to acquire and utilize calcium from soils

There is variation between plants in their ability to grow on low Ca soils. Plant species differ in both requirement in Ca supply to the roots and Ca demand per unit tissue weight. As a rule, the required supply (i.e., soil content or concentration in the soil solution) of Ca and the Ca content in the tissue are higher in

Differences in calcium efficiency may be related to acquisition by roots, or utilization for plant growth

The higher efficiency in calcium acquisition was related to higher root branching

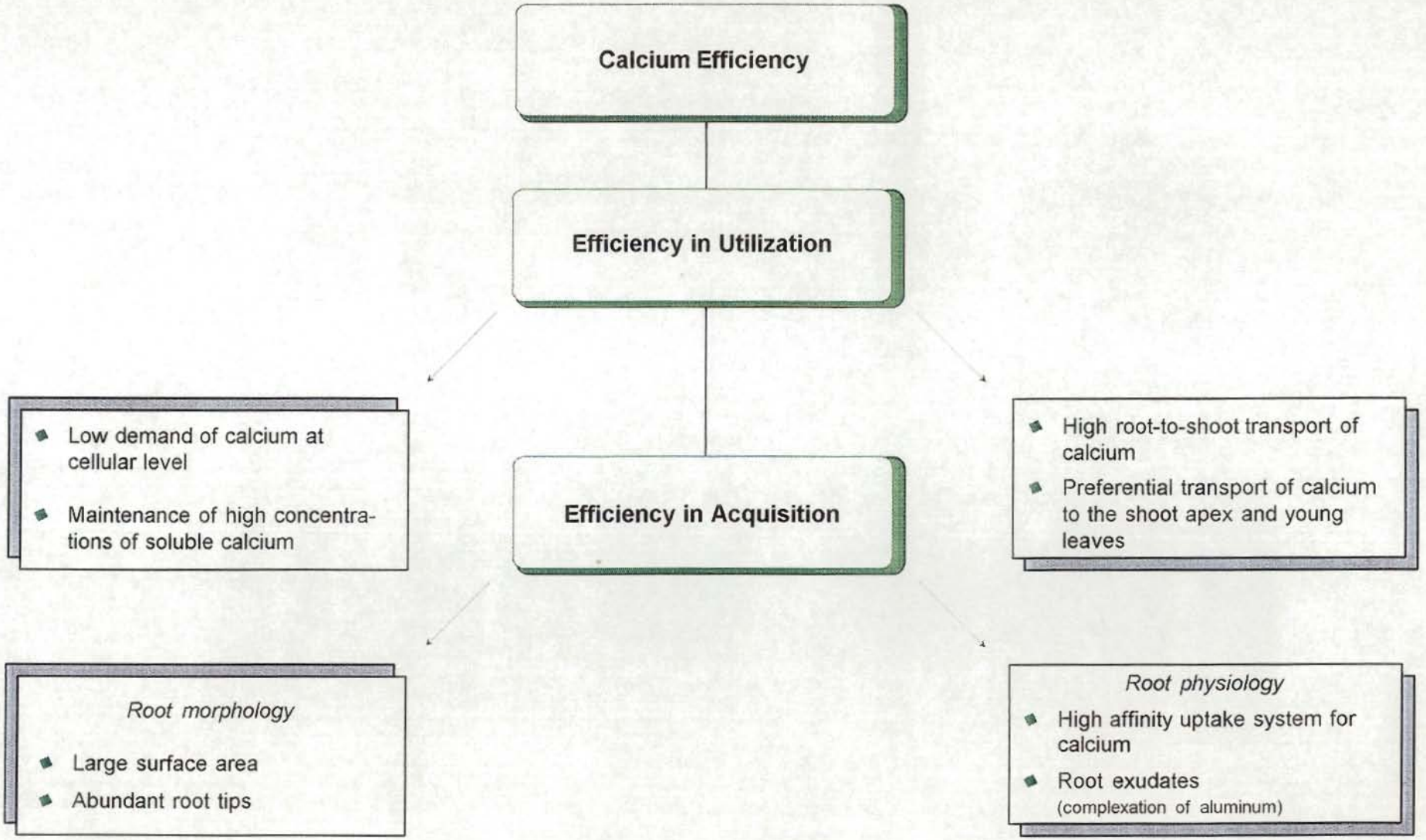
dicotyledonous species (e.g., legumes) than in monocotyledonous species such as forage grasses (Loneragan et al., 1968; Loneragan and Snowball, 1969; Islam et al., 1987). But also between species of grasses and dicots as well as between cultivars or ecotypes of a given species considerable differences exist in the apparent requirement and demand of Ca. According to these differences the terms "calcium-efficiency" and "calcium-inefficiency" have been introduced. From the agronomical or breeding point of view, for adaptation to acid mineral soils a high calcium-efficiency is achieved, i.e., genotypes which acquire greater amounts of Ca and produce a high yield in a soil low in available Ca.

Calcium efficiency may be related to a higher efficiency in utilization within the plant, or a higher efficiency in acquisition of Ca by the roots (Figure 1). Examples for a more efficient utilization of Ca within the shoot have been given for a Ca-efficient tomato cultivar (English and Barker, 1987) or cowpea cultivar (Horst et al., 1992), or by a higher proportion of Ca translocated to the shoot apex in a Ca-efficient tomato cultivar (Behling et al., 1989). Differences in efficiency in Ca acquisition between species and genotypes within a species are well documented and demonstrated by differences in Ca concentrations in the shoots of plants grown in the same solution (Loneragan et al., 1968; Islam et al., 1987) or the same soil.

Inter- and intraspecific variation in Ca efficiency has been demonstrated in several acid soil-adapted tropical forage grasses and legumes in field experiments conducted on an Oxisol of Carimagua (Colombia) (Tropical Pastures Program Annual Report, 1981). Among the grasses, *Brachiaria humidicola* CIAT 679 was the most Ca-efficient one, it had the lowest requirement for Ca supply (125 kg $CaCO_3$ ha^{-1}) and also the lowest internal Ca concentration (0.22% Ca in the dry matter). Glasshouse studies using acid soils of contrasting texture have indicated marked interspecific variation in Ca acquisition and internal utilization among 7 grasses and 12 forage legumes (Table 1; I.M. Rao et al., unpublished data). Recent work, supported in a BMZ project,

Figure 1

Components of calcium efficiency in plants



There is no knowledge on ecotypic differences in calcium acquisition and utilization by Arachis pintoi

Agronomic evaluation in the Cerrados of Brazil indicated ecotypic variation in dry season performance of Arachis pintoi

demonstrated higher Ca acquisition in *Brachiaria ruziziensis* compared to *Brachiaria dictyoneura*, leading to much higher Ca concentrations in the shoot dry matter and uptake of Ca in the above-ground biomass of *B. ruziziensis* (K. Haussler, GTZ Report, 1994). The higher efficiency in Ca acquisition in *B. ruziziensis* was related not to a higher root length but higher branching, i.e., more root tips which are the main sites of Ca uptake along the root axis (Marschner and Richter, 1974; Haussling et al., 1988).

Much of the 50 million hectares planted to *Brachiaria* species pastures in tropical America are now in a state of degradation owing to nutrient depletion. There is good evidence that inclusion of legumes can assist in reversing pasture degradation. *Arachis pintoi* forms stable grass-legume associations with the *Brachiaria* species. But there is no information on differences in Ca acquisition and utilization among different *A. pintoi* ecotypes now available. *A. pintoi* is better adapted to clay loam than sandy loam Oxisols which may be related to better water and Ca availability in the clay loam.

The Ca concentration per unit shoot dry weight is much higher in *A. pintoi* (dicot) compared to the forage grasses. In preliminary experiments with *A. pintoi* grown in two Oxisols (sandy loam, clay loam) the Ca concentration in the shoot dry matter was about 15 mg g^{-1} dry matter (Milz, unpublished). So far only a few data are available on Ca acquisition and internal utilization in a single ecotype, CIAT 17434, of *A. pintoi* (See Table 1; I.M. Rao et al., unpublished results). Shoot Ca uptake, at high Ca supply, was greater with clay loam than sandy loam soil.

Agronomic evaluation of thirty-three ecotypes of *A. pintoi* in the Cerrados of Brazil indicated ecotypic differences in tolerance to soil water deficits. Based on green leaf retention in the dry season, the performance of CIAT 22160 was markedly superior to CIAT 17434 (E. izarro, unpublished results). But there is no information on differences in Ca acquisition and utilization among *A. pintoi* ecotypes.

Table 1

Differences in shoot calcium uptake and calcium use efficiency in *Brachiaria* and *Arachis* species grown in low fertility sandy loam acid soil.

Species and Ecotype	Shoot Ca uptake (mg/pot)	Ca use efficiency (g/g)*
Brachiaria decumbens CIAT 606	20.1	211
Brachiaria brizantha CIAT 6780	19.9	170
Brachiaria dictyoneura CIAT 6333	11.5	187
Brachiaria humidicola CIAT 6369	9.5	187
Arachis pintoi CIAT 17434	60.5	34

* grams of forage produced per gram of total Ca uptake from soil

Improved screening procedures will be developed for tropical forage evaluation and improvement

Forage grasses and legumes are essential components of agricultural sustainability

2.4 Project outline

We intend to test two hypotheses:

(1) That differences in Ca acqusition among and within *Brachiaria* and *Arachis* species and ecotypes are related to their root architecture, cation exchange capacity and binding of Ca to root cell walls.

(2) That lower Ca concentrations in the shoot dry matter affect forage quality.

By testing these hypotheses and identifying plant attributes that contribute to greater acquisition and utilization of Ca, we should be able to develop improved screening procedures for tropical forage evaluation/ improvement. Higher Ca acquisition will enhance recycling of Ca in tropical pastures and reduce Ca losses from the system by leaching.

Grasses and legumes are known to contribute not only to animal production but also to soil fertility in tropical farming systems. Thus they are essential components of sustainability.

What is desirable from an animal nutrition point of view is the greater efficency in acquisition of Ca by roots and translocation to the shoots. There is a need to relate the efficiency of Ca acquisition to Ca activity in soil solution. This project will contribute to selection of high quality forages and will also have an additional spin-off on fertilizer management for pastures on low fertility acid soils. By relating Ca acquisition to soil Ca it will provide important information to growth of other crops on acid soils.

2.5 Ability of organization and individuals to undertake the research .

German and local universities will collaborate in the project

The project's principal CIAT scientists Drs. I. M. Rao (Project leader), C. E. Lascano, J. W. Miles, and P. C. Kerridge have long-term experience in the development of tropical forage germplasm, namely in the areas of plant nutrition/physiology, forage quality/animal nutrition, forage genetics/breeding, and soil fertility/ agronomy, respectively. They will be able to provide the required local supervision to the German doctoral student and the eventual B. Sc. students.

For the past 3 years, the CIAT Tropical Forages Program has been cooperating closely with the German project partner (Prof. H. Marschner) with special project funding from BMZ in a project entitled "Study of phosphorus dynamics in the rhizosphere of various grass and legume species growing in acid soils of Latin America".

2.6 Agricultural development and ecology implications of the project

Calcium efficient forages will contribute to sustainable livestock production

Development of calcium efficient forages that combine productivity and quality with adaptation to low fertility acid soils of the tropics, will contribute to sustainable livestock production.

In addition, the calcium efficient forages will enhance recycling of calcium in agropastoral systems, reduce calcium losses from the system by leaching, and contribute to sustainable land use systems in the humid and subhumid tropics.

3.0 Project Objectives

The project has a clear goal, which complements and integrates into the research of the CIAT Tropical Forages Program

The expected outputs will help to identify calcium efficient tropical forage grasses and legumes

Goal

To develop tropical forages with improved efficiency in acquisition and utilization of calcium from low fertility acid soils.

Project Purpose

To identify plant attributes that contribute to improved efficiency in acquisition and utilization of calcium in *Brachiaria* and *Arachis* in order to develop screening procedures to evaluate forage germplasm for efficiency in calcium acquisition and utilization.

Project outputs

The expected outputs from the above objectives are:

- Identification of *Brachiaria* and *Arachis* species and ecotypes with greater ability to acquire and utilize calcium.
- Identification of plant attributes that contribute to calcium efficiency in *Brachiaria* and *Arachis*.
- Selection of superior *Brachiaria* genepools (using new screening metholodology).

Benefits for Developing Countries and NARS

The results from the project will be presented at regional conferences organized by regional networks such as RIEPT and Agropastoral Network. Furthermore, final results of the project will be discussed in a 2-day workshop at CIAT.

The outputs of this project will contribute towards the development of forage components for farming systems on acid infertile soils of the humid and sub-humid tropics which is the broader goal of the Tropical Forages Program at CIAT.

4.0 Work Plan

The project will be coordinated by the Tropical Forages Program, and both German and Colombian students and scientists will carry out the research

The principal activities and subactivities of the project as they relate to the project's outputs are illustrated in Figure 2. The project organization concerning technical reporting and financial management is shown in Figure 3. Figure 4 shows the implementation schedule with the commencement and duration of each main activity.

The execution of the project in Palmira and Carimagua, Colombia will require three years. The project will be coordinated by Dr. I. M. Rao, Tropical Forages Program, CIAT, with assistance from other scientists from CIAT and Prof. H. Marschner from the University of Hohenheim, Germany.

The research will be carried out by a Ph. D. student and staff of German University and CIAT scientists (see also 5.0 Training)

Figure 2 shows the breakdown of the project structure with descriptions of the goal, purpose, outputs and activities.

Figure 2

Project Description

Structure Linking Project Activities to Project Outputs

Program Goal

To develop tropical forages with improved efficiency in acquisition and utilization of calcium from low fertility acid soils.

Project Purpose

To identify plant attributes that contribute to improved efficiency in acquisition and utilization of calcium in Brachiaria and Arachis in order to develop screening procedures to evaluate forage germplasm for efficiency in calcium acquisition and utilization.

Project Outputs

Activities

Identification of *Brachiaria* and *Arachis* species and ecotypes with greater ability to acquire and utilize calcium

- Select contrasting genotypes of *Brachiaria* and *Arachis* from agronomic evaluation experiments.
- Establish an experiment on a calcium deficient sandy loam acid subsoil with different levels of Ca supply as lime and gypsum.
- Determine dry matter partitioning among plant parts and leaf area production (three times during growing season), concentration of Ca and another mineral elements in the dry matter.
- Determine root biomass and root length distribution across the soil profile (up to 80 cm soil depth).
- Determine partitioning of nitrogen among soluble and total protein in leaves of different maturities.
- Identify Ca-efficient *Brachiaria* and *Arachis* ecotypes.

Identification of plant attributes that contribute to calcium efficiency in Brachiaria and Arachis

- Select contrasting genotypes of *Brachiaria* and *Arachis* from agronomic evaluation.
- Conduct a glasshouse experiment with sandy loan acid subsoil supplied with different levels and forms (lime, gypsum) of Ca, determine root architecture using minirhizotrons and measure Ca concentrations in root and shoots.
- Use of labelled isotope (^{45}Ca) technique for measurement of Ca uptake in different root zones (mature, elongating, tip) of primary and secondary roots, and of Ca transport to the shoots and young levels in particular.
- Determine short-term uptake of calcium (^{45}Ca) in roots exposed to solutions of different pH and concentrations of aluminum (water and sand culture experiments).
- Determine cation exchange capacity of the cell walls in roots and cell wall constituents and digestibility of leaf and stem tissue.
- Determine intracellular compartmentation and binding forms of Ca in leaves of different age.
- Determine cell wall constituents and digestibility of leaf and stem tissues.
- Relate compartmentation and binding forms of Ca with forage quality attributes.
- Develop a new screening procedure to evaluate Ca-efficiency.
- Relate Ca acquisition to Ca activity in soil solution.

Selection of superior *Brachiaria* genepools (using new screening metholodology)

- Grow out gene pools (advanced lines) from *Brachiaria* improvement program.
- Undertake restricted set of measurements on plant attributes as would be used by a Geneticist screening material.
- Validate laboratory findings with restricted set of animal feeding trials.
- Select Ca efficient *Brachiaria* gene pools.

Project management and dissemination of results

- Revise proposal together with donor.
- Provide progress, technical and financial reports.
- Report progress at Regional Network meetings.
- Publish results.
- Conduct a workshop at CIAT.
- Provide final report.

Figure 3

Project Organization Chart

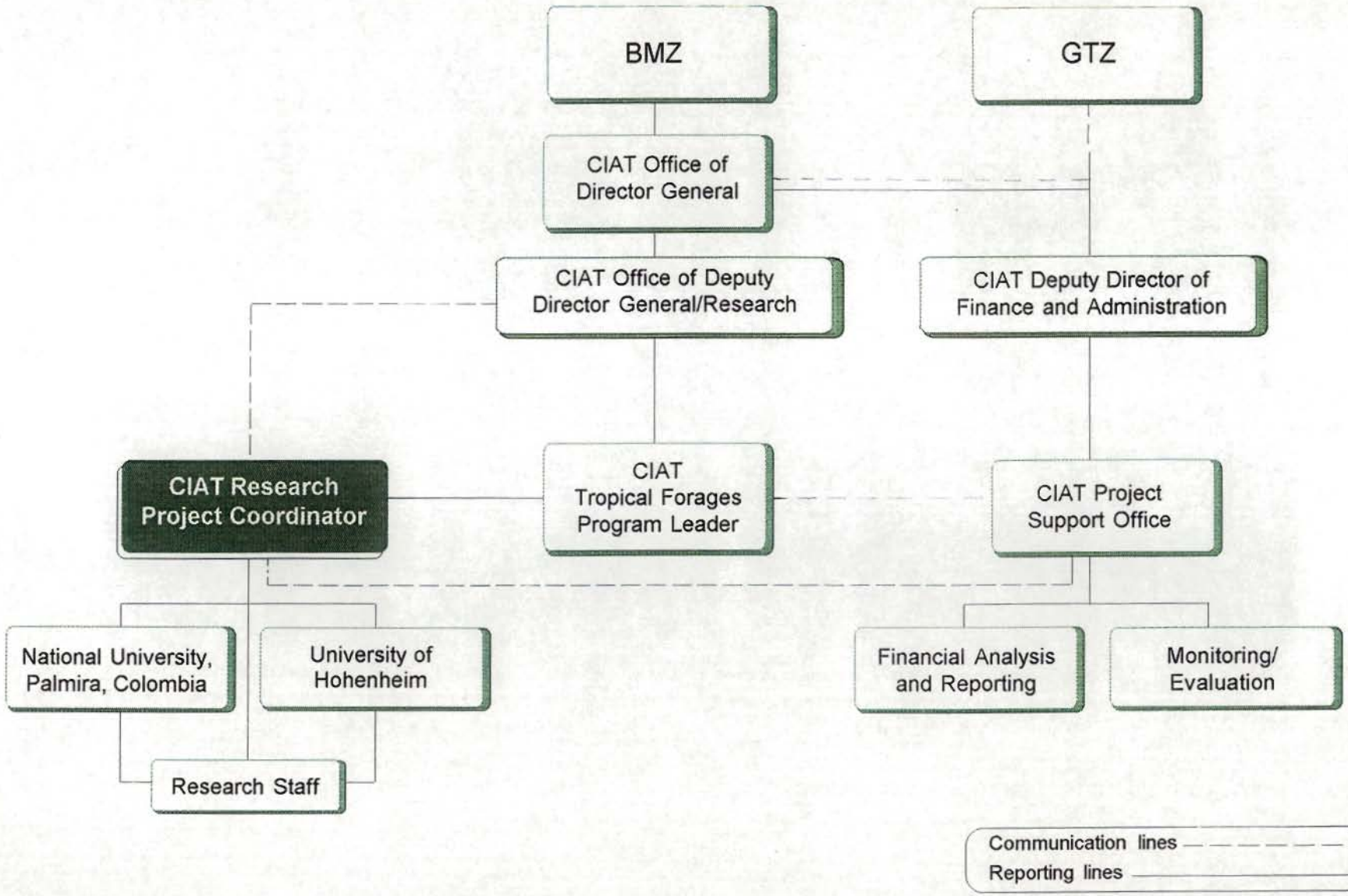
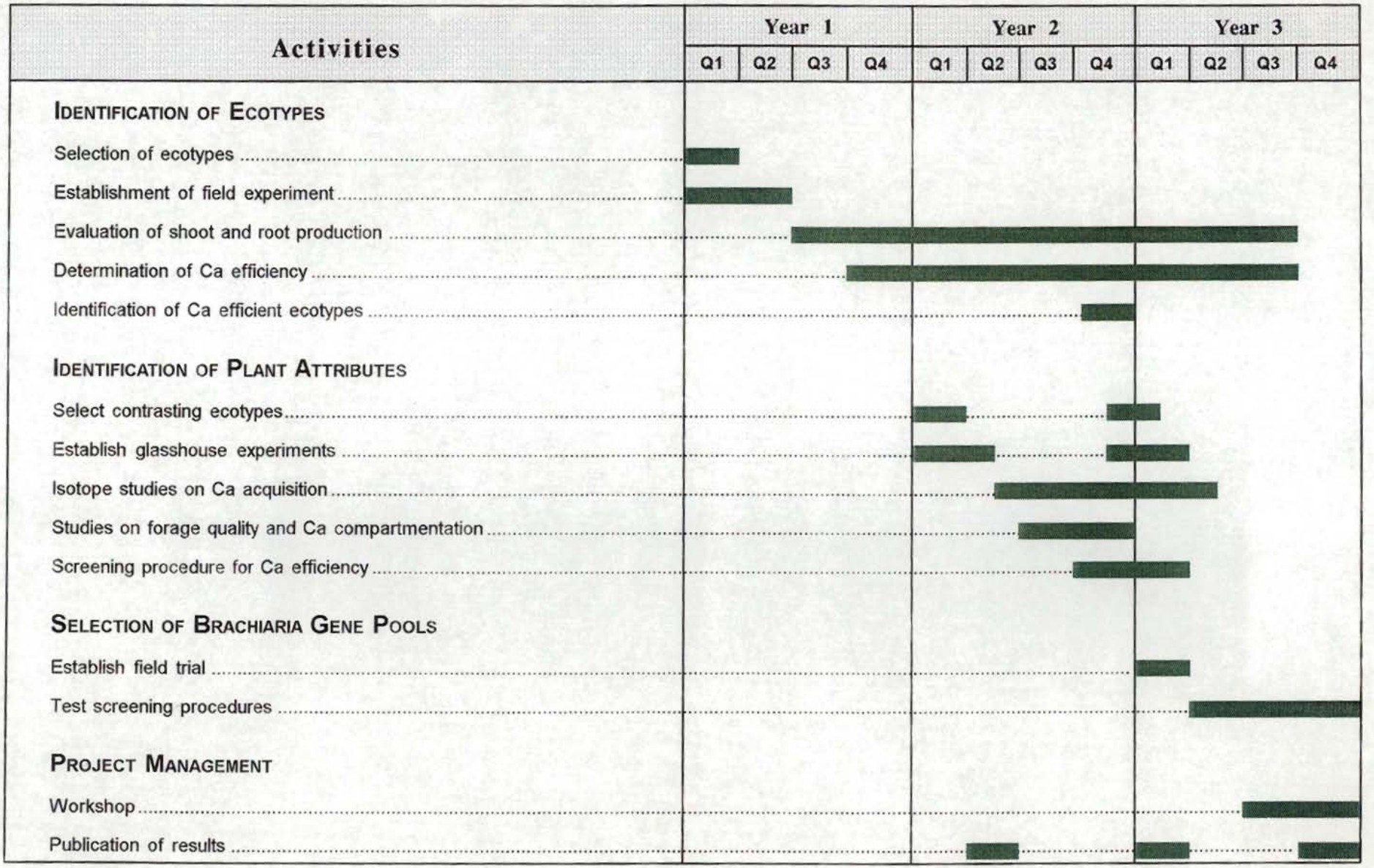


Figura 4

Project Implementation Schedule of Activities by Quarter



5.0 Training and Workshops

A German doctoral student from the University of Hohenheim will carry out the proposed research. He will work under the supervision of the project leaders, Dr. I. M. Rao (CIAT) and Prof. H. Marschner (University of Hohenheim).

The project will also provide the opportunity for two Colombian undergraduate students from the University at Palmira (Universidad Nacional), Colombia. According to its gender policy, CIAT will take care that both female and male students will participate in the project if they are equally talented.

A two-day workshop will be conducted at CIAT at the end of the project to discuss final results and their implications for future research on the development of forage components for sustainable agropastoral systems on low fertility acid soils of the humid and sub-humid tropics.

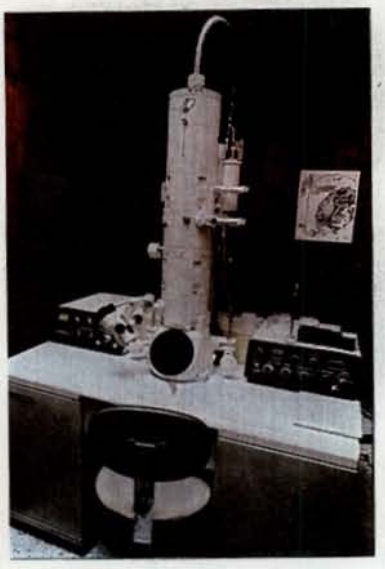
Students from the local university will be given the opportunity for undergraduate thesis research

6.0 Expected Patentable Research Results

CIAT endorses the principle of free access to research results. It supports this through publication of research findings in international journals and in-house documents.

There are no patentable results anticipated in this project.

7.0 Funding Requirements



7.1 Budget

The budgets for CIAT and the University of Hohenheim appear in Table 2. The CIAT budget will be administered by CIAT.

7.2 Budget notes

Personnel

The two positions (1 technician and 1 worker) budgeted for CIAT refer to assistance needed for one technician at CIAT-Carimagua for field research and one worker at CIAT-Palmira for glasshouse research.

The German doctoral student will carry out the proposed research with the help of a technician and a worker at CIAT (18 months) and at the University of Hohenheim (18 months). The doctoral student will be supported by two Colombian undergraduate students.

Research and operational expenses

As the project includes field and glasshouse research, there are substantial costs involved in the establishment of experiments, purchase of chemicals including radioisotopes, processing of samples and mineral analysis of samples.

Research results from the project will be published in three languages (English, German and Spanish).

Training and Workshops (CIAT budget)

- Provision is made in the project for training up to two B.Sc. students from a Colombian University who will receive a small allowance to do undergraduate thesis research.
- The workshop budgeted refer to a short (two-day) meeting at CIAT with the participation of CIAT scientists, the German doctoral student, and the scientists from NARS at the end of the project, in order to discuss final results and their implications for future research.

Travel (Hohenheim budget)

The amount budgeted for local travel refers to an absolute minimum necessary for the doctoral student to move between CIAT-Palmira and CIAT-Carimagua.

The international travel for the doctoral student and supervisors includes a provision for an eventual participation in an international congress. The German supervisor will travel to Colombia during Year 1 to visit field and glasshouse experiments and to discuss the project with CIAT scientists. The CIAT supervisor will travel to Germany at the end of Year 2 to discuss the progress made.

Table 2

CENTRO INTERNACIONAL DE AGRICULTURA TROPICAL – CIAT

BMZ – Improving efficiency in calcium acquisition and utilization by forage grasses and legumes

Proposed Budget

(IN US$)

INSTITUTION/LINE ITEM	Year 1	Year 2	Year 3	Total
CIAT				
Personnel				
Technician (1)	12,000	12,600	–	24,600
Worker (1)	7,000	7,500	8,000	22,500
Total personnel	**19,000**	**20,100**	**8,000**	**47,100**
Research and Operations				
Supplies and services	12,000	10,000	–	22,000
Laboratory Analysis	6,000	8,000	4,000	18,000
Total research and operations	**18,000**	**18,000**	**4,000**	**40,000**
Training and workshops				
B.Sc. students (2)	1,000	1,000	–	2,000
Workshops	–	–	3,000	3,000
Total training and workshops	**1,000**	**1,000**	**3,000**	**5,000**
Indirect costs (20%)	7,600	7,820	3,000	18,420
TOTAL CIAT	**45,600**	**46,920**	**18,000**	**110,520**
Hohenheim University				
Personnel				
Doctoral student (1)	30,000	30,000	30,000	90,000
Total personnel	**30,000**	**30,000**	**30,000**	**90,000**
Research and Operations				
Supplies	2,000	8,000	12,000	22,000
Publications	–	2,000	2,000	4,000
Total research and operations	**2,000**	**10,000**	**14,000**	**26,000**
Travel				
Local (PhD. Student)	3,000	3,000	3,000	9,000
International (PhD. student)	2,500	–	2,500	5,000
(Supervisor)	5,000	5,000	–	10,000
Total travel	**10,500**	**8,000**	**5,500**	**24,000**
TOTAL HOHENHEIM UNIVERSITY	**42,500**	**48,000**	**49,500**	**140,000**
GRAND TOTAL	**88,100**	**94,920**	**67,500**	**250,520**

BMZ-CALC
23-Jun-95
PROPOSED

Juan A. Garafulic
Financial Controller

8.0 References

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Appendix A-1

Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

C.V.

Idupulapati M. Rao

Position in Project:

Research Coordinator, Plant Nutritionist/Physiologist.

International Research Experience:

Centro Internacional de Agricultura Tropical (CIAT)
Cali, Colombia (1989- present)
Plant Nutritionist/Physiologist, Tropical Forages Program

Responsible for identifying adaptive attributes of tropical forage species to low fertility acid soils; developing reliable screening indices for plant evaluation and plant improvement; investigating plant-soil interrelationships with respect to recycling of nutrients in pasture-based production systems.

University of California, Berkeley, California, USA (1984-89)
Assistant Specialist, Department of Plant and Soil Biology

Research on mechanisms of plant adaptation to low nutrient supply in sugar beet and soybean; use of light scattering and chlorophyll fluorescence techniques for mineral deficiency diagnosis; role of phosphorous in photosynthesis, carbon partitioning and carbon export; limiting factors in photosynthesis.

University of Illinois
Urbana-Champaign, Illinois, USA (1982-83)
Research Associate, Department of Plant Biology

Research on mechanisms of plant adaptation to water stress in sunflower; leaf nutrient status (particularly magnesium and potassium) and photosynthetic response to low leaf water potentials.

Cornell University, Ithaca, New York, USA (April-May, 1982)
Boyce Thompson Institute for Plant Research
Visiting Scientist, Environmental Biology

Research on effects of sulfur dioxide (SO_2) pollution on photosynthesis, leaf conductance and stomatal metabolism of peas.

University of Illinois at Chicago
Chicago, Illinois, USA (1981-82)
Research Associate, Department of Biological Sciences

Research on the role of light modulation of enzymes in the mechanisms of stomatal movement; effects of sulfite and arsenite on stomatal metabolism.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT)
Patancheru, Andhra Pradesh, India (1979-81)
Plant Physiologist, Pulse Physiology

Research on development of field screening techniques to evaluate pigeonpea genotypes for their tolerance to abiotic stresses, particularly salinity and waterlogging; growth analysis of pigeonpea hybrids and their parents; response of pigeonpeas to environment and cultural practices such as spacing, plant population, irrigation and nutrients.

Supervisory Experience:

Supervision of Ph.D. (3) and Undergraduate degree (3) thesis projects for students registered in the Universities from USA, Germany and Colombia.

Areas of Specialization:

Plant traits and mechanisms for adaptation to low fertility acid soils; nutrient acquisition and nutrient cycling in pasture-based production systems; physiological responses of plants to edaphic and climatic stresses.

Professional Memberships:

- American Society for Plant Physiology
- American Society of Agronomy
- Crop Science Society of America
- Soil Science Society of America

Education:

Ph.D. Plant Physiology
Sri Venkateswara University, India (1978)
Dissertation Title: Carbon metabolism and water relations of six woody weeds and their modification by paraquat and 2,4,5-T.

M.S. Botany, Plant Physiology
Bhopal University, India (1973)

B.S. Botany, Chemistry, Zoology
Andhra University, India (1971)

Languages:

English -Fluent
Telugu -Fluent
Hindi -Conversational
Spanish -Conversational

Citizenship:

Indian

Country of Residency:

Colombia

Publications:
(Author of 52 articles and 6 book chapters, a list of last 5 years)

Rao, I. M. and Kerridge, P.C. 1994. Mineral nutrition of forage *Arachis*. *In:* P. C. Kerridge and W. Hardy (eds.). The biology and agronomy of forage *Arachis*. pp. 71-83. CIAT, Cali, Colombia.

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Rao, I. M., Borrero, V., Ayarza, M.A. and Garcia, R. 1994. Adaptation of tropical forage species to acid soils: The influence of varying phosphorus supply and soil type on plant growth. In: R. A. Date, N. J. Grundon, G. E. Rayment and M. E. Probert (Eds.), Plant-Soil Interactions at Low pH: Principles and Management. Kluwer Academic Publishers, Dordrecht, The Netherlands, in press.

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Fisher, M.J., Lascano, C.E., Thomas, R.J., Ayarza, M.A., Rao, I. M., Rippstein, G. and Thornley, H.J.M. 1993. An integrated approach to understand soil-plant-animal interactions on grazed legume-based pastures on tropical acid soils. Proc. XVII International Grassland Congress, New Zealand & Queensland, Australia. pp. 1903-1204.

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Ayarza, M.A., Rao, I.M., Thomas, R.J., Fisher, M.J., Lascano, C.E. and Herrera, P. 1993. Standing root biomass and root distribution in *Brachiaria decumbens/Arachis pintoi* pastures. Proc. XVII International Grassland Congress, New Zealand & Queensland, Australia. p. 1921.

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Rao, I.M., Ayarza, M.A., Thomas, R.J., Fisher, M.J., Sanz, J.I., Spain, J.M. and Lascano, C.E. 1992. Soil-plant factors and processes affecting productivity in ley farming. *In:* Pastures for the tropical lowlands: CIAT's contribution. pp 145-175. CIAT, Cali, Colombia.

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Terry, N. and Rao, I.M. 1991. Nutrients and photosynthesis: iron and phosphorus as case studies. In: J.R. Porter and D.W. Lawlor (eds), Plant Growth: Interactions with Nutrition and Environment. pp. 55-79. Cambridge University Press, Cambridge, England.

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Fredeen, A.L., Raab, T.K., Rao, I.M. and Terry, N. 1990. Effects of phosphorus nutrition on photosynthesis in *Glycine max*. Planta 181:399-405.

Rao, I.M., Arulanantham, A.R. and Terry, N. 1989. Leaf phosphate status, photosynthesis and carbon partitioning in sugar beet II. Diurnal changes in sugar phosphates, adenylates and nicotinamide nucleotides. Plant Physiol. 90:820-826.

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Appendix A-2

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

C.V.

Horst J. Marschner

Position in Project:

German Project Coordinator

International Research Experience:

Member of the Deutsche Akademie der Naturforscher - Leopoldina
1993

University Hannover
Dr. rer hort. honoris causa, Faculty of Horticulture. 1989

University of Hohenheim
Professor of Plant Nutrition. Since 1977

Commonwealth Scientific and Industrial Research Organization (CSIRO), Adelaide, Australia
Division of Horticultural Research. 1973-1974

Technical University of Berlin
Institutie of Plant Nutrition. 1966-1976
Full Professor and Director

University of California, Berkely, USA
Department of Soil Science and Plant Nutrition. 1965-1966
Research fellow

University of Hohenheim
Institute of Plant Nutrition. 1960-1966
Associate Professor

German Academy of Sciences, Berlin
Institute of Crop Research Gatersleben. 1958-1960
Research Associate

University of Jena
Institute of Agricultural Chemistry. 1955-1958
Research fellow

Education:	**University of Jena** Study of Agriculture and Chemistry 1951-1955 Ph.D., **University of Jena** 1957
Main Research Interests:	Mineral metabolism of plants (uptake, translocation, function of mineral elements). Genotypical differences in mineral metabolism of crop plants (deficiency, toxicity). Adaptation of plants to adverse soil conditions (acid or alkaline soils, salinity, water logging). Yield formation ("source-sink-relationship"). Environmental aspects of fertilizer application (nitrogen, heavy metals). Plant-microbial symbiosis: Endo- and ectomycorrhizae, Rhizobium. Joint research projects on plant nutrition and crop production, Universities and Research Institutions, e.g. in the P.R. of China (increase in efficiency of fertilizer application), Israel (iron acquisition; drought stress tolerance), Niger (increase in nutrient use efficiency), Syria (phosphorus efficiency), Turkey (micro-nutrient supply in citrus and cotton, zinc efficiency), and Colombia (phosphorus efficiency of pasture legumes and grasses).
Languages:	German - Fluent English - Fluent
Citizenship:	German
Country of Residency:	Germany

Publications:

301 publications in national and international scientific journals. Textbook: Mineral Nutrition of Higher Plants, Academic Press, first edition 1986; second edition 1995 (in press).

Relevant Publications
119 publications for the past 5 years

Marschner, H. and Römheld, V. *Strategies of plants for acquisition of iron.* Plant Soil 165, 261-274 (1994)

Marschner, H. and Dell, B. *Nutrient uptake in mycorrhizal symbiosis.* Plant Soil 159, 89-102 (1994)

Dinkelaker, B., Hahn, G. and Marschner, H. *Non-destructive methods for demonstrating chemical changes in the rhizosphere.* II. Application of methods. Plant Soil 155/156, 71-74 (1993)

Marschner, H. *Nutrient dynamics at the soil-root interface (rhizosphere).* In: Mycrorrhizas in Ecosystems, D.J. Read *et al. eds.*, pp. 3-12. CAB International, Wallingford Oxon, UK. (1992)

Marschner, H. *Mechanisms of adaptation of plants to acid soils.* Plant Soil 134, 1-20 (1991).

Marschner, H. *Nutrient dynamics in the rhizosphere.* 3 Simposium Nacional sobre Nutrición Mineral de las Plantas, Palma (Baleares) 18.-20. Sept. pp. 1-13 (1990).

Marschner, H., Römheld, V. and Zhang F.S. *Mobilization of mineral nutrients in the rhizosphere by root exudates. In*: Ed. Masyoshi Koshino. Transactions 14TH Intern. Conference of Soil Science, Kyoto, Japan, Vol. II, pp. 158-163. (1990).

Ernst, M., Römheld, V. and Marschner, H. *Estimation of phosphorus uptake capacity by different zones of the primary root of soil-grown maize (Zea mays L.)* Z. Pflanzenernähr. Bodenk. 152, 21-25 (1989)

Dinkelaker, V., Römheld, M. and Marschner, H. *Citric acid excretion and precipitation of calcium citrate in the rhizosphere of white lupin (Lupinus albus L.)* Plant Cell Environ. 12, 285-292 (1989)

Marschner, H. and Cakmak, I. *High light intensity enhances chlorosis and necrosis in leaves of zinc, potassium and magenesium deficient bean (Phaseolus vulgaris) plants. J. Plant Physiol. 134, 308-315 (1989)*

Marschner, H. and Häussling. *Organic and inorganic soil phosphates and acid phosphatase activity in the rhizosphere of 80-year-old Norway spruce (Picea abies (L>) Karst.) trees. Biol. Fertil. Soils 8, 128-133 (1989)*

UNIVERSITÄT HOHENHEIM
INSTITUT FÜR PFLANZENERNÄHRUNG

Prof. Dr. Dr. h. c. Horst Marschner

Postadresse/Postal address:
Universität Hohenheim, Institut für Pflanzenernährung (330), 70593 Stuttgart

Appendix B

Partner Confirmation Letter

Fruwirthstr. 20
70599 Stuttgart

den

11.1.1995

Dr. P. Kerridge
Leader of the Tropical Forages Program
C I A T
A.A. 6713
Cali, COLOMBIA

Dear Dr. Kerridge,

I am writing to confirm my commitment and that of the Institute of Plant Nutrition of this University, to the special project entitled

"Calcium acquisition and utilization by forage grasses and legumes"

which will be proposed to BMZ.

Yours sincerely,

CIAT has in-house facilities for the production of high-quality training materials and video programs for scientific and extension agricultural activities.

This proposal was produced and published, using CIAT's computer layout and graphic composition facilities and outside low-cost copying services.