Tropical Grasses and Legumes:

Optimizing genetic diversity for multipurpose use

Project IP-5

Courtesy of Chaisang Phaikaew

Summary
Annual Report 2004

CIAT
Centro Internacional de Agricultura Tropical
International Center for Tropical Agriculture

SUMMARY
ANNUAL REPORT
2004

PROJECT IP-5
Tropical Grasses and Legumes: Optimizing genetic diversity for multipurpose use

Centro Internacional de Agricultura Tropical
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1.0 Project Overview: IP5: Tropical Grasses and Legumes: Optimizing Genetic Diversity for Multipurpose use

Objective: To develop and utilize superior gene pools of grasses and legumes for sustainable agricultural systems in subhumid and humid tropics.

Outputs
Optimized genetic diversity for quality attributes, for host-parasite-symbiont interactions, and for adaptation to edaphic and climatic constraints, for legumes and selected grasses.
Selected grasses and a range of herbaceous and woody legumes evaluated with partners, and made available to farmers for livestock production and for soil conservation and improvement.

Gains: Defined genetic diversity in selected grass and legume species for key quality attributes, disease and pest resistance, and environmental adaptation. Known utility in production systems of elite grass and legume germplasm. New grasses and legumes will contribute to increased milk supply to children, cash flow for small livestock and non- livestock farmers, while conserving and enhancing the natural resource base.

Milestones
2004 Defined utility of *Flemingia*, and *Lablab* hay as feed resources for dairy cows.
Opportunities identified in Africa to promote the utilization of forages developed by CIAT.
2005 Methods and tools available to enhance targeting and adoption of multipurpose forage germplasm in smallholder production systems in Central America.
A new *Brachiaria* hybrid with better adaptation to dry season and with higher seed yield available for release in the dry tropics.
2006 Widespread adoption of improved forage technologies in the subhumid and humid tropics (e.g. Central America and SE Asia).
A *Brachiaria* hybrid with resistance to some species of spittlebug, with high forage quality and with higher seed production than the available commercial hybrid (Mulato) is available to farmers in the tropics.

Users: Governmental, nongovernmental, and farmer organizations throughout the subhumid and humid tropics who need additional grass and legume genetic resources with enhanced potential to intensify and sustain productivity of agricultural and livestock systems.

Collaborators: National, governmental, and nongovernmental agricultural research and/or development organizations; AROs (Universities of Hohenheim and Göttingen, CSIRO, JIRCAS, ETHZ); private sector (e.g. Papalotla).

CGIAR system linkages: Enhancement & Breeding (30%); Livestock Production Systems (15%); Protecting the Environment (5%); Saving Biodiversity (40%); Strengthening NARS (10%). Participates in the Systemwide Livestock Program (ILRI) through the Tropileche Consortium.

CIAT project linkages: Genetic resources conserved in the Genetic Resources Unit will be used to develop superior gene pools, using where necessary molecular techniques (SB-2). Selected grasses and legumes will be evaluated in different production systems of LAC, Asia and Africa using participatory methods (SN-3) to target forages (PE-4, SN-2) and to assess their impact (BP-1) for improving rural livelihoods and conserving natural resources (PE-2, PE-3, PE-4).

2.0 Research Strategy and Activities

Strategy: To accomplish its goal and the main objective, the Forage Project relies on CIAT's forage germplasm collection [housed in the Genetic Resources Unit (GRU)], which, with more than 20,000 accessions, is the largest forage germplasm collection in the CGIAR and on collaborative research with a range of public and private sector partnerships. From past multilocational evaluation through networking (RIEPT), a number of key genera of grasses (*Brachiaria, Paspalum, Panicum*) and legumes (*Arachis, Stylosanthes, Desmodium*, *Cratylia*) with high potential for animal feed and natural resource conservation have been identified. Within the key species in these genera, elite germplasm accessions are identified and characterized in the target area to develop cultivars with high feed quality and broad adaptation to biotic and abiotic stress factors. The improved genotypes are tested with partners in production systems using farmer participatory methods and NARS and private seed companies in the region release those selected cultivars.

It follows, that our main strategy is to exploit genetic diversity from collections of natural germplasm of selected key forage species based on strict prioritization of potential impact. Artificial hybridization to create novel genetic combinations is used in cases where clear constraints have been identified and where evaluation of large germplasm collections has failed to identify the required character combinations (e.g. spittlebug resistance and edaphic adaptation in *Brachiaria* or anthracnose resistance and seed yield in S*tylosanthes*).

Activities: To implement the R&D strategy a multidisciplinary team together with partners carries out the following main activities:

a) Define quality and antiquality factors in grasses and legumes to develop better screening procedures and identify nutritional synergism among species
b) Define mechanisms of adaptation of grasses and legumes to low fertility soils and drought to develop better screening protocols, e.g., for resistance to spittlebug and tolerance to edaphic and climatic constraints
c) Improve grasses and legumes with well-defined constraints of economical importance through selection in core collections and through artificial hybridization
d) Evaluate selected grasses and legumes for multipurpose use in smallholder livestock/ cropping systems
e) Link forage and socio economic databases to GIS to facilitate targeting of germplasm to different agro-ecosystems.
f) Create partnerships with other CIAT Projects and with NARS, NGO's, and private sector organizations to deliver superior grasses and legumes to farmers

3.0 Target Areas

Tropical grasses and legumes being developed at CIAT are targeted to three main agroecological zones in the tropics: Savannas, Forest Margins and Hillsides. These agroecosystems are characterized by low fertility soils and variable rainfall, ranging from sub-humid (600- 1500 mm/year rainfall and 4-8 months dry season) to humid (2,000 to 4,500 mm/year rainfall and limited or no dry season stress) areas.

Traditional land use in some savannas regions of Colombia, Venezuela and Brazil is characterized by extensive cow-calf operations with low management input and almost no

purchased inputs, with corresponding low productivity. However, the area planted to improved grass pasture has expanded but the proportion of degraded pastures has also increased alarmingly. Intensive tillage for annual crop production has also resulted in soil degradation leading to severe compaction in the profile and increased runoff and erosion.

Variable topography and drainage and high weed potential generally characterize the Forest Margins in Central America, the Amazon, Africa and SE Asia. Many regions are far removed from markets and suffer from lack of infrastructure. Land is used predominantly for subsistence agriculture following slash and burn of the forest by smallholders and for dual-purpose cattle in cut and carry systems or in grass-based pastures in different stages of degradation.

Many soils that support crop and livestock systems managed by smallholders in subhumid areas of Central America, the Andean zone, Africa, and SE Asia are in different stages of degradation, which leads to deforestation. In addition, farmers in these regions have shortage of labor to collect feed from forests or wastelands and as a consequence livestock intensification is severely limited.

It follows, that a common constraint across the three agroecosystems being targeted by CIAT's Forage Team is low quantity and quality of forage biomass available to feed livestock in pasture or cut and carry systems and as a result animal production is low and environmental degradation is high. Thus improved forage options can improve livelihoods of smallholders while contributing to reduce deforestation and restore degraded lands in the tropics.

4.0 Beneficiaries

Large, medium and small livestock producers are capturing the benefits of the improved grasses and legumes being developed by CIAT. Increasing incomes and urbanization in developing countries is creating a higher demand for livestock products (meat, eggs and dairy products) than staple crops. Because the poor derive a greater proportion of their income from livestock than do the wealthy, and because of the huge expected growth in demand for livestock products, the livestock revolution could become a key means of alleviating poverty in the next 20 years. To make this a reality, livestock production in developing countries will need to double by 2020 and to meet this goal improved forage- based feeding systems need to be developed and adopted by farmers.

5.0 Project Log-Frame

2004-2006

Area: Genetic Resources Research
Project:IP-5 Tropical Grasses and Legumes: Optimizing Genetic Diversity for Multipurpose Use
Project Manager: Carlos E. Lascano

Narrative Summary	Measurable Indicators	Means of Verification	Important Assumptions
Goal To contribute to the improved welfare of small farmers and urban poor by increasing milk and beef production while conserving and enhancing the natural resource base	≠ New cultivars of grasses and legumes used by farmers. ≠ Raised productivity of livestock and crops while protecting biodiversity and land in savannas, forest margins and hillsides	Statistics and case studies on socio-economic benefits and natural resource conservation in smallholder livestock farms in the subhumid and humid tropics	Policies are put in place by governments to favor sustainable livestock and forage development in marginal areas occupied by small farmers
Purpose To identify and deliver to farmers superior gene pools of grasses and legumes for sustainable agriculture systems in subhumid and humid tropics.	≠ Demonstrated economical and ecological benefits of multipurpose grasses and legumes to livestock and crop farmers in tropical regions of Latin America, Africa and South East Asia	≠ Range of genetic variation in desirable plant traits ≠ Performance of forage components in systems	≠ Support from traditional and nontraditional donors ≠ Effective collaboration: ≠ CIAT's Projects ≠ ARO's, partners and farmers, NGOs
Outputs 1. Grass and legume genotypes with high forage quality attributes are developed.	≠ Defined utility of *Flemingia*, and *Lablab* hay as a feed resource for dairy cows by 2004. ≠ Determined utility of legume mixtures for increasing protein supply in ruminants while reducing methane emissions by 2005 ≠ New *Brachiaria* genotypes with superior forage quality for improved animal performance characterized by 2006	≠ Demonstrated differences under field conditions ≠ Scientific publications ≠ Annual Reports ≠ Theses	≠ Effective collaboration with CIAT Projects (PE-2), AROs, partners and farmer groups
2. Grass and legume genotypes with known reaction to pests and diseases and interaction with symbiont organisms are developed.	≠ Efficient screening method to assess *Rhizoctonia* resistance in *Brachiaria* developed by 2004. ≠ Role of endophytes on drought tolerance determined under field conditions by 2004. ≠ QTL's for resistance to spittlebug and high aluminum in the soil in *Brachiaria* are available for marker-assisted selection by 2005. ≠ *Brachiaria* genetic recombinants with combined resistance to different species of spittlebug are available by 2006.	≠ Demonstrated differences under field conditions ≠ Scientific publications ≠ Annual Reports ≠ Theses	≠ Effective collaboration with CIAT Projects (SB-1, SB-2), AROs, partners and farmer groups
3. Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed.	≠ Improved accessions of *Vigna* and *Lablab* with adaptation and known value to farmers in hillsides of Central America are available to partners by 2004. ≠ Defined variability for nitrification inhibition in *Brachiaria* genotypes by 2005. ≠ *Brachiaria* genetic recombinants with resistance to low P and high aluminum in the soil and with drought tolerance are available by 2006.	≠ Demonstrated differences under field conditions ≠ Scientific publications ≠ Annual Reports ≠ Theses	≠ Effective collaboration with CIAT Projects (SB-1, PE-2, PE-4), AROs, partners, NGOs and farmer groups
4. Superior and diverse grasses and legumes delivered to NARS partners are evaluated and released to farmers	≠ Scaling process of *Vigna*, *Lablab* and *Cratylia* and improved *Brachiaria* are in place in Central America by 2004. ≠ New market opportunities in Central America for processed forages assessed by 2006. ≠ A Decision Support Tool for targeting forages to different environments and production systems in Central America is available by 2005 ≠ Opportunities identified in Africa to promote the utilization of forages developed by CIAT by 2004 ≠ An information network on forages and effective forage multiplication systems are established in benchmark sites in SE Asia by 2004. ≠ Improved multipurpose grasses and legumes result in increased on-farm milk, meat, and crop production, and reduced labor requirements in benchmark sites in SE Asia by 2005. ≠ Widespread adoption of forage technologies in the subhumid and humid tropics by 2006. Improved processes for scaling-out the impacts of forage technologies on farms in SE Asia.	≠ Promotional publication 4≠Newsletters 4≠Journal 4≠Extension booklets ≠ Surveys on adoption impact of new grasses and legumes: 4≠Seed sold 4≠Area planted 4≠Production parameters 4≠Environmental/socioeconomic indicators	≠ Effective collaboration with CIAT Projects (PE-2, SN-1, SN-2, SN-3, BP-1 and Ecoregional Program), partners, NGOs and farmer groups

2005-2007

Area: Genetic Resources Research
Project: Tropical Grasses and Legumes: Optimizing Genetic Diversity for Multipurpose Use
Project Manager: Carlos E. Lascano

NARRATIVE SUMMARY	MEASURABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
Goal To contribute to the improved welfare of small farmers and urban poor by increasing milk and beef production while conserving and enhancing the natural resource base	⋕ New cultivars of grasses and legumes used by farmers. ⋕ Raised productivity of livestock and crops while protecting biodiversity and land in savannas, forest margins and hillsides	Statistics and case studies on socio-economic benefits and natural resource conservation in smallholder livestock farms in the subhumid and humid tropics	Policies are put in place by governments to favor sustainable livestock and forage development in marginal areas occupied by small farmers
Purpose To identify and deliver to farmers superior gene pools of grasses and legumes for sustainable crops-livestock systems in subhumid and humid tropics.	⋕ Demonstrated economical and ecological benefits of multipurpose grasses and legumes to livestock and crop farmers in tropical regions of Latin America, Africa and South East Asia	⋕ Range of genetic variation in desirable plant traits ⋕ Performance of forage components in systems	⋕ Support from traditional and nontraditional donors ⋕ Effective collaboration: ⋕ CIAT's Projects ⋕ ARO's, partners and farmers, NGOs
Outputs 1. Grass and legume genotypes with high forage quality attributes are developed.	⋕ Determined the utility of legume mixtures for increasing protein supply in ruminants while reducing methane emissions 20% by 2005 ⋕ Selected at least 10 Brach aria hybrids (sexuals) with high digestibility (>60%) and crude protein (> 10%) by 2006 ⋕ The little bag silage technology with selected forage species adopted by at least 100 small farmers in Honduras and Nicaragua, results in 20-30%% milk yield increase in the dry season by 2007	⋕ Demonstrated differences under field conditions ⋕ Scientific publications ⋕ Annual Reports ⋕ Theses	⋕ Effective collaboration with CIAT Projects (PE-2), AROs, partners and farmer groups
2. Grass and legume genotypes with known reaction to pests and diseases and interaction with symbiont organisms are developed.	⋕ Validated a rapid screening method, with a capacity to evaluate 1000 genotypes in five days, to assess *Rhizoctonia* resistance in *Brachiaria* by 2005 ⋕ At least 10 *Brachiaria* genetic recombinants with combined resistance to at least three species of spittlebug in Colombia are available for regional testing in Central/South America by 2006 ⋕ At least three *Brachiaria* genetic recombinants with resistance to *Rhizoctonia* are available for regional testing in Central/South America by 2007	⋕ Demonstrated differences under field conditions ⋕ Scientific publications ⋕ Annual Reports ⋕ Theses	⋕ Effective collaboration with CIAT Projects (SB-1, SB-2), AROs, partners and farmer groups

3. Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed.	⇗# Two improved accessions of Vigna and one of Lablab multiplied (500 or 100 kg of seed produced, respectively) and distributed to two national partners (DICTA, INTA), one NGO (SERTEDESO), one farmer organization (Campos Verdes) one development project (GTZ), in Honduras and Nicaragua by 2005 ⇗# A new *Brachiaria* hybrid (CIAT 36087, cv. Mulato-II) with better adaptation to acid soils and tolerance to dry season (50% higher dry season forage yield on acid soils than the current hybrid cultivar), and resistance/tolerance to at least three Colombian species of spittlebugs, and with 2-3 times higher seed yield available for release (50 tons of commercial seed available) by 2006 ⇗# Defined the genetic variability for nitrification inhibition in at least 500 *Brachiaria* hybrids by 2007	⇗# Demonstrated differences under field conditions ⇗# Scientific publications ⇗# Annual Reports ⇗# Theses	⇗# Effective collaboration with CIAT Projects (SB-1, PE-2, PE-4), AROs, partners, NGOs and farmer groups
4. In partnership with NARS, superior and diverse grasses and legumes are evaluated and disseminated through participatory research.	⇗# New market opportunities for processed forages assessed trough surveys to at least 100 farmers with and without livestock in Honduras and Nicaragua by 2005 ⇗# *Brachiaria brizantha* cv. Toledo seed produced (500 kg to 1 t) by one farmer enterprise (PRASEFOR). in Honduras by 2006 ⇗# A forage production systems established with >5000 farmers in 4 countries of SE Asia supported by >50 experienced staff and key technical information about forage technologies and their development by 2006 ⇗# At least 5,000 ha of Brachiaria hybrid (Mulato II) planted in Colombia, Honduras, Nicaragua and Mexico by 2007 ⇗# Improved multipurpose grasses and legumes result in 20% more on-milk, and in 30% reduced labor requirements in benchmark sites in SE Asia by 2007.	⇗# Promotional publication ⇗# Newsletters ⇗# Journal ⇗# Extension booklets ⇗# Surveys on adoption impact of new grasses and legumes: ⇗# Seed sold ⇗# Area planted ⇗# Production parameters ⇗# Environmental/socioeconomic indicators	⇗# Effective collaboration with CIAT Projects (PE-2, SN-1, SN-2, SN-3, BP-1 and Ecoregional Program), partners, NGOs and farmer groups

6.0 List of IRS in the IP-5 Project

Lascano Carlos E, Project Manager and Animal Nutritionist; Headquarters
Argel Pedro, Forage Agronomist: 60% CIAT and 40% Papalotla, San José, Costa Rica
Cardona Cesar, Entomologist (Host Plant –Resistance): 50% in IP-5 and 50% in IP-1; Headquarters
Holmann Federico, Animal Production Systems/Economics: 50% CIAT and 50% ILRI; Headquarters
Horne Peter M., Forage Agronomist: 80% IP5 and 20% Regional Office; CIAT- Asia
Kelemu Segenet, Pathologist: 70% in IP-5 and 30% PE-1; Headquarters
Miles John, Plant Breeder: 100% in IP-5; Headquarters
Peters Michael, Forage Biologist: 100% in IP-5; Headquarters
Rao Idupulapati, Plant Nutritionist/Physiologist: 30% in IP-5, 30% in IP-1 and 40% in PE-2; Headquarters
Schmidt Axel, Forage Agronomist: 100% IP-5, Managua, Nicaragua
Stur Werner, Forage Agronomist: 50% IP-5; Asia

7.0 List of Partners

Main collaborators in CIAT

Debouck Daniel, SB-1	Roothaert Ralph (Africa), ILRI/CIAT-PRGA
Tohme Joe, SB-2	Sanz José I, PE-3
Barrios Edmundo, PE-2	White Douglas
Rondón Marco, PE-2	Oberthur Thomas, Hyman Glen, Jones Peter, PE-4
Ayarza Miguel, PE-2 (National Coordinator, Honduras)	Hernández Luis Alfredo, Roa José I., SN-3
Lefroy Rod, (SE Asia: Regional Coordinator, Laos)	Posada Rafael, BP-1
Kirby Roger (Africa: Regional Coordinator, Uganda)	Rivas Libardo, BP-1
	Cock James, Fruits

Main collaborators outside CIAT

Forage Quality: Rolando Barahona, CORPOICA, Colombia; Juan Carulla, U. Nacional, Colombia; Kreuzer Michael and Hess Dieter, ETH, Zurich, Switzerland.
Genetic Improvement of *Brachiaria*: do Valle Cacilda B., EMBRAPA, Brazil
Pests (spittlebug): Corpoica Macagual: Field evaluation of Brachiaria genotypes for resistance to spittlebugs; Colegio de Postgraduados de Chapingo, Mexico and U. de Vicosa, Brasil. M.Sc. Thesis on mechanisms of resistance to spittlebug species in *Brachiaria*
Diseases (anthracnose): Chakraborty Sukumar, CSIRO, Australia and Jairo Osorio, CORPOICA, Colombia
Endophytes: Schardl Christopher, Department of Plant Pathology, University of Kentucky, USA; Dongyi Huang CATAS, The People's Republic of China; Sakai Tomoko, JICA, Japan.
Adaptation to abiotic stress factors: Claassen N., University of Göttingen, Germany; Wenzl, P., CAMBIA, Canberra, Australia; Prof. Horst W. University of Hannover, Germany; Gaume, A., Oberson A. and Frossard E., ETH, Zurich, Switzerland; Dr. Shinano T., Osaki M., and Tadano T, Hokkaido University, Sapporo, Japan; Subbarao G. V., Ishikawa T. and Okada K., JIRCAS, Tsukuba, Japan;

On-station and on-farm evaluation/diffusion of forages: Restrepo Jose y Villeda Daniel, FIDAR**,** Colombia; Velásquez Jaime, U de la Amazonia, Colombia; Medrano Jorge y Parra Fredy, CORPOICA, Colombia; Hidalgo Carlos, Lobo Marco, and Sánchez William, Beatriz Sandoval and María Mesén, MAG, Costa Rica, Burgos Conrado, DICTA, Honduras; Uebelhoer Konrad, Gettkant Andreas, gtz, Honduras; Ibrahim Muhammad, CATIE, Costa Rica; Posas Marlene Iveth, SERTEDESO, Honduras; Mena Martin and Molina José A., INTA, Nicaragua; Schultze-Kraft Rainer, University of Hohenheim, Germany; Hoffmann Volker, University of Hohenheim, Germany; Yi Kexian, CATAS, Hainan, China; Le Hoa Binh, NIAH, Truong Tan Khanh, Tay Nguyen University, Vietnam; Ed Magboo, PCARRD, Philippines; Ibrahim and Yakob Pangedongan, Dinas Peternakan Samarinda, Indonesia; Chaisang Phaikaew and Ganda Nakamanee, DLD, Thailand; Viengsavanh Phimphachanhvongsod and Bounthavong Kounnavongsa, NAFRI, Laos; Viengxay Photakoun NAFES, Laos; Sorn San, NAHPIC, Cambodia; Eduardo Stern, Papalotla, Mexico

8.0 Financial Resources

Source	Amount (US Dollars)*	Proportion (%)
Unrestricted Core	348,816	18%
Restricted Core	286,099	14%
Carry Over	117,557	6%
Sub–Total	**752,472**	**38%**
Special Projects (Headquarters)	910,196	46%
Special Projects (Asia)	317,631	16%
Total Project	**1,980,229**	**100%**

9.0 Research Highlights

Improvement of *Brachiaria* for biotic and abiotic stresses (Outputs 2 and 3 from Logframe)

The apomictic *Brachiaria* hybrid (CIAT 36087--Mulato 2) in the pre-release stage combines resistance to at least two species of spittlebug, adaptation to acid infertile soils and tolerance to drought. Significant progress has also been made in developing sexual *Brachiaria* hybrids that combine spittlebug resistance with Al resistance. Selected sexual genotypes are being used in recurrent selection to generate superior apomicitic hybrids of *Brachiaria* for release as cultivars.

- **Selected sexual *Brachiaria* hybrids with high levels of resistance to several species of spittlebug in the greenhouse and field:** In 2004, intensive screening of selected hybrids was conducted under greenhouse and field conditions with three species of spittlebug. A set of 731 pre-selected sexual (SX03) hybrids was simultaneously screened for resistance to *A. varia*, *A. reducta*, and *Z. carbonaria.* We found that 40% of the sexual hybrids combined low damage levels and high levels of antibiosis resistance to all three species of spittlebug. Sexual hybrids (22) previously selected in Palmira under greenhouse conditions were included in a field test with

artificial infestation of spittlebug. All of the sexual hybrids showed adequate levels of field resistance to four species (*Aeneolamia varia, Zulia carbonaria, Z. pubescens*, and *Mahanarva trifissa*) of spittlebug.

- **Selected sexual *Brachiaria* hybrids with resistance to Rhizoctonia foliar blight**: A rapid detached leaf inoculation method coupled with a new rating scale (0- 5) was used to screen 745 sexual *Brachiaria* genotypes for resistance to Rhizoctonia foliar blight. Ten percent (73 genotypes) of the plant materials that showed average disease ratings below 3.0 in the screen with detached leaves were then evaluated in the greenhouse by inoculating complete plants under high humidity. Among the 73 selected *Brachiaria* genotypes evaluated in the greenhouse, 26% had high level of resistance to Rhizoctonia foliar blight.

- **Selected sexual and apomictic *Brachiaria* hybrids with high levels of resistance to Al under low nutrient conditions**: As reported previously, high values of total root length and low values of mean root diameter after exposure of plants to toxic level of Al in solution are indicative of resistance to Al. Using this selection criteria, 3 sexual hybrids (SX03NO/0846, SX03NO/2367, SX03NO/0881) were identified with greater level of Al resistance than that of the original sexual parent (*B. ruziziensis* 44-02). One apomictic hybrid (BR02NO/1372) was outstanding in its level of Al resistance. This hybrid is also resistant to spittlebug and has greater fine root (which give plants the ability to acquire nutrients from low fertility soils) development than *B. decumbens* CIAT 606 in the absence of Al in solution.

- ***Brachiaria* hybrid cultivar Mulato 2 (pre-release stage) combines good adaptation to acid infertile soils, drought tolerance and resistance to spittlebug**. Results from a field trial that included 4 *Brachiaria* hybrids (BR98NO/1251; BR99NO/4015; BR99NO/4132; Mulato 2) showed that the spittlebug resistant *Brachiaria* hybrid (Mulato 2) performed better than the other hybrids into the third year after establishment in the acid infertile soils in the Llanos. The superior performance of Mulato 2 was associated with its ability to acquire great amounts of nutrients, particularly calcium and magnesium from low fertility soils. Leaf and stem N content and shoot N uptake values indicated that Mulato 2 can also use N efficiently to produce green forage in the dry season.

- **Genetic variability exists for nitrification inhibition (NI) in *Brachiaria humidicola*.** Significant differences were found among accessions (10) of *B. humidicola* in total and specific NI activity of root exudates. Several accessions of *B. humidico*la with NI activity that is two to three times higher than the standard cultivar CIAT 679 used for nitrification inhibition experiments at JIRCAS and CIAT were identified. The accession CIAT 26159 was repeatedly tested along with the standard cultivar CIAT 679, and the high NI activity nature of confirmed by JIRCAS. The existence of substantial differences among accessions of *B. humidicola* in NI activity of root exudates demonstrates the genetic nature of this plant attribute and the possibility of improving further the NI ability in *B. humidicola* through systematic evaluation of germplasm and breeding.

Development of multipurpose legumes for smallholder systems (Outputs 1 and 3 from Logframe)

Progress was made in defining the effect of planting site on quality of shrub legumes and in selecting legumes with drought tolerance as green manures for the dry hillsides of Central America where traditional legumes such as Mucuna used by farmers in the more humid areas do not perform well.

- **Selecting appropriate planting sites improves the feeding value of *Calliandra calothyrsus*.** While the tanniniferous shrub legume *Calliandra calothyrsus* is widely used by smallholders to supplement dairy cattle and goats in hillsides of Kenya, farmers in Colombia have hardly adopted this supplementation strategy. We hypothesized that this was mainly due to differences in the forage quality of this legume in the two countries. To test this hypothesis, an *in vitro* experiment was performed to compare the nutritional value and the ruminal fermentation characteristic of *C. calothyrsus* var. Patulul cultivated in sites in Colombia (Santander de Quilichao—acid-infertile soils—1000 masl) and in Kenya (Embu--fertile soils--1480 masl). Although the foliage of the two provenances of *C. calothyrsus* tested had similar contents of OM, CP and NDF, they differed in nearly all fermentation properties and the material from Kenya showed a higher apparent nutrient degradability. These differences in nutritive value were mainly explained by lower levels of condensed tannins in the foliage from Kenya. Work is in progress to define environmental factors (e.g. soil type and fertility) responsible for differences in forage quality and type and concentration of condensed tannins of a range of tanniniferous shrub legumes.

- **The drought tolerant *Canavalia brasiliensis* is an excellent green manure option for dry hillsides of Central America**. In farmers fields in hillsides of Central America soil fertility is declining and weeds are becoming a major problem. In order to overcome these limitations we have been working with local farmer organizations to introduce, evaluate and promote the use of legumes as green manures. At the SOL Wibuse site in San Dionisio, Nicaragua, four crop rotation treatments (maize/beans, maize/natural fallow, maize/*Canavalia brasiliensis* and maize + cowpea/*C. brasiliensis*) were evaluated. Results indicated that after two years of rotation the highest yields were observed in the maize + cowpea / *C. brasiliensis* and maize / *C. brasiliensis* rotation plots. The higher maize yields with *C. brasiliensis* as green manure were associated with the high biomass production and permanent soil cover with green foliage provided by this legume during the entire dry season.

Constraints for adoption and Impact of Forage R&D (Output 4 from Logframe)

This year we documented constraints associated with adoption of added value forage technologies by smallholders and the impact of improved *Brachiaria* in Central America. We are also documenting the success story of seed production of Mulato by smallholders in Thailand.

- **Constraints for animal feed production as an objective of poor farmers in Central-America were identified.** Given that animal feed related activities (production of dry season feed for sale to cattle owners) have been identified as promising income generating options for poor farmers in the hillsides of Central-America, an analysis was carried out to identify (mainly household related) factors inducing or inhibiting farmers to opt for production of animal feed. Results indicate that farmers owning land and cattle are more likely to include animal feed as a research and production objective than the poorer farmers, except for those who are not self-sufficient in maize. Farmers without full decisive power over their land are reluctant to engage in animal feed production for the market. Whereas research and development work on added value forage technologies to link farmers to markets can continue to be directed at all farmer categories in Central-American hillsides, special attention is justified for farmers without full land ownership and those who depend on outside jobs for acquired basic grains for their food security.

- ***Brachiaria* grasses have had a major impact in tropical milk production systems in Mexico and Central America.** A study was carried out to estimate the adoption and impact

of *Brachiaria* grasses released through the forage network (RIEPT) operated by CIAT in the 80's and 90's, using as a basis seed sold during the period 1990-2003. Results indicated that during this period the annual increase rate (32 to 62%) in seed sales was high in all countries and that total area planted with *Brachiaria* cultivars during this period represented 6.5% of the total area of permanent pastures in Mexico, 12.5% in Honduras, and 18.7% in Costa Rica. The main beneficiaries from the adoption of *Brachiaria* cultivars have been small and medium size producers oriented toward dairy and to a lesser extent to beef production. For example, in Costa Rica more than 55% of the national milk production but only 18% of the beef produced in 2003 was due to the marginal increase in the productivity of *Brachiaria* pastures compared to the traditional technology from degraded or naturalized pastures.

- **Smallholder farmers producing seed of Mulato in Thailand have an assured market and earn more income.** *Brachiaria* Mulato hybrid was by CIAT to Southeast Asia in 1996 as part of a large *Brachiaria* variety trial. In Thailand, The Thai Department of Livestock Development (DLD) selected Mulato and seed production trials were initiated in 2003 with 7 small farmers. This year 1793 small farmers planted 700 ha of Mulato to produce 143 Tons of seed thanks to a guaranteed market by Papalotla. Earnings with Mulato seed production are 25% higher / ha than with the traditional seed production of Ruzi grass.

10.0 Problems encountered and their solutions

The consensus among staff of the project continues to be that security in Colombia is a main problems affecting fieldwork. It appears that the situation is improving.

Other problems affecting the work plans of staff in the project are:

- **Support from field operations is inadequate** (i.e. spatial heterogeneity in the field, limitations for irrigation). The problem is not the fault of Field Operations since it seems that they are not being given adequate resources to do what needs to be done.
  - **Solution:** Revise allocation of operational and capital funds to support Field Operations

- **Limited possibilities of outposted staff to carry out research related activities:** Several factors contribute to this: a) most funding for forage related work in the regions comes from special projects SP and most donors do not want to fund research (particularly true in Asia and Central America), and b) to many non-research activities (i.e. development of new proposals to ensure continuation of work and of funds to cover part of the salary of the staff positions, administrative matters, daily project management, maintenance of vehicles, dealing with visitors). A major consequence of the great number of non-research activities is limited time to carry out research and to write papers for peer reviewed journals, which has implication in the performance appraisal (PA) of outposted staff.
  - **Solution:** Revise criteria for evaluating performance of outposted staff

- **Reliance on Special Project (SP) funding in regions could severely limit research and scaling efforts**: The full dependence on SP funding for Forage R&D work in the regions reduces flexibility in cases where funding may be interrupted even temporarily. This puts at risk the payoff of previous investments and the possibility to show impact.
  - **Solution:** Device a mechanism for allocating bridging core funds to support work in the regions

11.0 Proposed plans for the next 5 years

On- going Brachiaria Improvement Program

Our focus will continue to be on developing apomictic *Brachiaria* hybrids with adaptation to biotic (spittlebug and rhizoctonia foliar blight resistance) and abiotic (acid soils, drought and poor drainage) stresses, and with high forage quality and seed yield. To reach this objective we will implement recently developed screening methods, initiate work on mechanisms affecting adaptation to drought and seek funding to work on tolerance to poorly drained soils.

Spittlebug

- **Initiate studies to assess the resistance of genotypes to adult feeding of different species.** Screening for spittlebug has been limited to selecting genotypes with antibiotic resistance to nymphs. In the field pastures of *Brachiaria* are subject to attacks of both nymphs and adults and the damage in the plant caused by adults can be as severe as the damage caused by nymphs.

- **Identify partners in ARO and donor support to study the biochemical resistance of *Brachiaria* to spittlebug.** Identification of the biochemical mechanism of antibiotic resistance in *Brachiaria* will facilitate the development of biochemical and/or molecular markers for the screening process.

Rhizoctonia foliar blight

- **Implement screening procedure to handle large number of genotypes**
  - First screen- Laboratory: Inoculated detached leaves in petri dishes
  - Second screen- Greenhouse: Genotypes selected with detached leaf method will be grown in pots in the greenhouse and inoculated under high humidity conditions.

Edaphic constraints

- **Study mechanisms associated with phosphorus (P) uptake and Plant use efficiency.** The focus on screening *Brachiaria* hybrids for edaphic constraints will continue to be in Al resistance under low nutrients. However, studies are needed to define the mechanisms responsible for the superior adaptation of *Brachiaria decumbens* under low P conditions in order to help develop an additional screening procedure.

Drought

- **Study mechanism associated with drought tolerance.** Currently genotypes selected for spittlebug, and Al resistance are evaluated under field conditions to determine performance under acid- low fertility soils and dry season conditions. To increase the selection pressure for drought tolerance we need to understand the different plant mechanisms associated with this trait. Thus studies in the greenhouse will be undertaken with contrasting genotypes exposed to two levels of moisture to define shoot and root traits that contribute to superior adaptation to drought.

Poor soil drainage

- **Seek extra funding to initiate studies on adaptation to poorly drained soils.** There are large areas in tropical regions (i.e. the Atlantic region in Central America, piedmont of the llanos of Colombia) where poor soil drainage is a major constraint for commercial Brachiaria cultivars. To undertake this task we need to find additional human and financial resources to support the Plant Nutritionist working on abiotic constraints in forages.

Forage quality

- **Implement the screening procedure for digestibility and protein in a selected sexual population.** We have now standardized a protocol to estimate in vitro digestibility and crude protein using near-infrared reflectance spectrometer (NIRS). Thus what we need to do now is implement the screening procedure using replicated plants in pots.

Genetic improvement of *Brachiaria humidicola*

Among the different *Brachiaria* species *B. humidicola* has a number of important commercial attributes such as high adaptation to acid infertile soils, tolerance to poorly drained soils and to heavy grazing and capacity to inhibit nitrification (conversion of ammonium to nitrate) in soil. Some negative attributes of the commercial *B. humidicola* cultivar are susceptibility to spittlebug, low forage quality and low seed yield.

Recent results in collaboration with JIRCAS indicate that there are accessions of *B. humidicola* with greater capacity to inhibit nitrification than the commercial cultivar CIAT 679. In addition, the germplasm collection held at CIAT contains accessions that are putatively sexual. This opens up the option of initiating a breeding program by making crosses.

With the current level of funding we can only undertake some limited work on the improvement of *B. humidicola*. What we propose to do in the following years is:

- Screen the collection for capacity to inhibit nitrification in collaboration with JIRCAS
- Confirm sexuality of accessions (11) in the collection by carrying out progeny tests in the field
- Perform crosses and determine quality of seed produced.

Legume germplasm development

Our future efforts will continue to focus on the development of forages for mixed crop-livestock systems. In these more intensive systems the need for legumes is great particularly for dry season feeding and to contribute to soil conservation and improvement. We have also seen the potential utility of high quality legumes grown by farmers to feed monogastrics.

Shrub legumes are a good alternative to overcome feed shortages in critical dry periods in livestock systems. However, there are few high quality forage shrub legumes available adapted to acid soils. In addition, many farmers in subhumid areas are demanding herbaceous legumes with dry season tolerance to be used as green manure and to supplement crop residues.

To address these demands we will evaluate new core collections of woody and herbaceous legumes for adaptation to abiotic and biotic constraints within a systems perspective as follows:

- ***Desmodium velutinum*.** Within the collection of shrub legumes in the GRU, *D. velutinum* is one that has high forage quality. We want to examine the collection in terms of adaptation to soils of variable pH and fertility, persistence under cutting and grazing, variation in forage quality and seed yield.

- ***Canavalia brasiliensis* as dry season feed and green manure.** Work in Central America has shown that *C. brasiliensis* is very vigorous and drought tolerant. Thus we need to explore the genetic diversity for key agronomic traits within the collection held at CIAT.

- ***Leucaena diversifolia***. There are few options of shrub legumes for higher altitudes. Among the shrub legume species available, *Leucaena diversifolia* appears to be one that is well adapted to acid soils and mid-high altitudes. Accessions include material available in the GRU and collections obtained from CSIRO, ICRAF and ILRI. We will attempt to get accessions from the U of Hawaii.

- **Legumes for monogastrics (swine, fish and poultry) in LAC and Asia.** Legumes (grain and foliage) for feeding monogastric animals should be highly productive and of high quality. Thus the challenges ahead are to a) select of forage legumes with high quality and low antinutritional factors, b) define post harvest processing of grain and foliage for leaf meal production to reduce antinutritional factors, c) determine animal responses and d) link farmers to markets.

Development and delivery of improved forages in regions

Forage R&D in Africa: We will continue to place high priority in identifying opportunities for R&D work in forages in Africa through the development of proposals for funding. Specifically we will seek collaboration with the TSBFI for developing proposals that aim to improve soil condition in mixed crop-livestock systems through grasses and legumes selected by the Forage Project. Finally, we will continue to respond to forage germplasm requests from initiatives led by CIAT and NARS in different regions.

Forage R&D in Asia: The regional AusAID project (the Forages for Smallholders Project- FSP) was a *"proof of concept"* project. Working in 7 countries, a small suite broadly adapted of varieties was identified and the potential for considerable impacts confirmed. AusAID agreed to fund a bi-lateral project to take these results one-step further and demonstrate that impacts could be delivered on a larger scale. This resulted in the Forages and Livestock Systems Project (FLSP) in Laos; a *"proof of delivery"* project that ends in 2005.

At the same time, the Asian Development Bank (ADB) agreed to continue to fund the regional project FSP (now called Livelihood and Livestock Systems Project – LLSP) to develop participatory methodologies for dissemination of forage technologies and to address other production and marketing constraints in smallholder livestock systems. This project will also end in 2005.

The Asia Forage Team is exploring ways to continue the work to scale-out the impact-yielding forage/livestock systems that have been developed. What is needed is a fully-fledged

development project to build on the experienced teams, the technologies, the methodologies and the impacts that have emerged from the FSP, LLSP and FLSP.

A Capacity Building project between the Laos National Agriculture and Forestry Research Institute (NAFRI) and CIAT (US$500,000) is expected to commence in January 2005. This project is designed to build a bridge between the end of the FLSP and the start of the PLDP (Participatory Livestock Development Project), which is a $10 million investment project in Laos for the Asian Development Bank. CIAT and ILRI are participating in the preparation of the project through a PPTA **(**Project Preparation and Technical Assistance) grant.

Forages for monogastrics is a new area of research identified by the Asia Team as having high priority and payoff. During this year, ACIAR invited CIAT to develop the proposal: "Forage legume supplementation of village pigs in Laos" with an indicative budget of Aust $ 400k. The proposed project will a) define criteria for selecting forage legumes for pig feeding, b) generate information on the nutritional value for pigs of selected forage legumes and c) integrate forage legumes in existing pig production systems as part of diets composed of other locally available feed resources (primarily new varieties of cassava, sweet potato and maize)

Forage R&D in LAC: Results from past work in Central America indicated the need to further develop forage alternatives for the dry season such as silage and hay. Both livestock or non-livestock owners can produce these silages and hays for self consumption or for sale provided they are exposed to simple technologies. Thus research is needed to define the usefulness and acceptability by farmers of such forage conservation technologies through on-station and on-farm studies.

Further research is also needed on the adaptation of new forage-based products to smallholder farm constraints to facilitate a market linkage between producers and end users. Success in this area would have an impact on income generation and livelihoods of smallholder farmers.

The efficiency of approaches facilitating innovation versus more traditional extension approaches of forage technologies on sileage technologies needs to be evaluated (i.e. promotion of innovation versus promotion of adoption).

The mentioned research questions are the core of the recently funded BMZ proposal 'Demand-Driven Use of Forages in Fragile, Long Dry Season Environments of Central America to Improve Livelihoods of Smallholders".

Performance Indicators

1.0 Technologies, Methods, Tools and Mechanisms

Forage Cultivars Released

Asia

CATAS in China released two cultivars during the last year. These are

- Reyan 11- *Paspalum atratum* BRA 9610 introduced by CIAT
- Reyan 13 - *Stylosanthes sympodialis* CIAT 1044, introduced from CIAT (in 1984)

LAC

The *Brachiaria* hybrid Mulato 2 (in pre-release stage) is under regional evaluation and basic seed is being multiplied for formal release in 2005.

Forage Accessions Multiplied and Distributed

Asia
The Livelihood and Livestock Systems Project (LLSP) distributed 111 kg of seed of 37 varieties and legumes to project collaborators and other research and development projects in Southeast Asia.

LAC
Seed Unit Palmira: Multiplied more than 1 t of seed of which 545.7 kg, (total for 12 accessions) was seed of *Cratylia argentea*. Significant quantities of *Lablab purpureus* (189.25 kg, 50 accessions) and *Canavalia brasiliensis* (132.0, 1 accession) were also produced. Seed distributed to 10 different countries was about one-fifth of the total produced (222.34 kg).

Seed Unit Atenas: A total of 1084.1 kg of experimental and basic seed was either produced at the Seed Unit or procured from associated collaborators. The bulk of the seed was formed by *Cratylia argentea* (195.0 kg) and *Brachiaria* hybrid cv. Mulato (740.5 kg). A total of 379.7 kg of experimental and basic seed was delivered in response to 49 seed request from 9 countries.

Elite *Brachiaria* hybrids developed

Resistance to spittlebug: a) Apomictic hybrids (11) "pre-selected" for Mexican conditions showed high levels of antibiosis resistance to *Prosapia simulans*, one of the most important spittlebug species affecting *Brachiaria* in Mexico and Central America; b) A high proportion (40%) of the sexual hybrids evaluated in 2004 were found to be resistant to three species *(A. varia, A. reducta* and *Z. carbonaria*) of spittlebug found in Colombia.

Resistance to Rhizoctonia foliar blight: Using detached leaves 73 (10% of the total) sexual hybrids had visual scores of less than 3 (lesion area of 6- 15.5%), Among the 73 selected *Brachiaria* sexual genotypes that were tested in the greenhouse, 19 genotypes (26%) had high level of resistance to the fungus.

Resistance to high Al in the soil: Using screening procedure to evaluate aluminum resistance, 3 sexual hybrids (SX03NO/0846, SX03NO/2367, SX03NO/0881) were identified with greater level of Al resistance than that of the original sexual parent. One apomictic hybrid (BR02NO1372) that was outstanding in its level of Al resistance is also resistant to spittlebug.

Resistance to drought: Results from a field study showed that *Brachiaria* hybrid cv Mulato 2 (CIAT 36087) is superior to cv. Mulato (CIAT 36061) in terms of dry season tolerance under low fertility acid soil conditions in the Llanos of Colombia

Elite legume species and accessions being multiplied for regional testing

- *Cratylia argentea:* CIAT 18516/18668, 18674, 22406, 22409, 22408, 18957, 22375, 22402, 22389, 22401 y 22388. Selected for high dry matter yield

- *Flemingia macrophylla:* CIAT 17403, 21090, 18437, 21083 from the first collection, and the accessions 870, 857 and 780 from a second collection. Selected for high dry matter yield and acceptable forage quality

- *Lablab purpureus*: CIAT 22770, 21603, 22768, 22598, 22604, 22653, 22723, 22766, 22660, 22663, 22735, 17197 y 22660. Selected for high dry matter yield

- *Vigna unguiculata*: IT89KD-288, IT86D-715, IT6D-733, IT95K-1088-2, IT95K-1088-4, IT93K-573-5, IT89KD391, IT86D-719, IT90K-284-2, IT96D-740, 9611, IT98K-131-2, IT97K-1069-2, IT97K-10696, IT97K-825-3, IT97K-461-4, IT98K-476-8, IT97K-494-3, IT95K-52-34, Verde Brazil, IT98K-412-8 and materials from CIDICCO. Selected for high dry matter yield and grain production.

- *Canavalia brasiliensis*: CIAT 17009, 808, 8557 y 17012. Selected for dry matter yield and tolerance to drought. A large collection of 53 accessions is in the process of evaluation.

- *M. pruriens* cv. Jaspeada-106, *M. pruriens* CIAT 9349, *M. pruriens* cv. IRZ-99, *M. pruriens* cv. Utilis-109. For equal or higher dry matter yield as compared to the control.

- *Desmodium velutinum*: CIAT 33443, 23985, 33352,13953, 23994, 23081, 13218,23983, 23982, 23981, 23276, 33463, 33003, 33996, 23928 y 23396. For high dry matter yield and forage quality.

- *Centrosema pubescens* CIAT15160, *Desmodium ovalifolium* CIAT 13651, *Leucaena leucocephala* CIAT 17263, and *Leucaena diversifolia* CIAT 17388.

Methodologies Developed

- A detached leaf inoculation method coupled with a rating scale was developed to pre-select large number of *Brachiaria* hybrids for resistance to Rhizoctonia foliar blight.

- A methodology to detect with NIRS differences in CP and IVDMD between *Brachiaria* hybrids planted as spaced plants in the field was developed and tested.

Tools developed

- Summarized information on tropical forage adaptation and use from available literature and experiential sources was included in the SoFT database (forage selection tool based on the experiences of more than 50 forage specialists).

- Advances were made in the creation of an SDSS (Spatial Decision Support Systems) called CaNaSTA (Crop Niche Selection for Tropical Agriculture) that incorporates spatial capabilities into an agricultural DSS.

Mechanisms Defined

Collaborative research conducted with Hokkaido University in Japan generated the first evidence based on ^{27}Al NMR analysis that organic acids within root tissue help detoxify aluminum in non-accumulator species such as the *Brachiaria* hybrid cv Mulato

2.0 Publications (see Annex for List of Publications)

Journal Papers

Published**: 25**
Accepted (In press): **5**
Submitted: **7**

Conference and Workshop Proceedings: 47

Working Documents and Technical Bulletins: **15**

Invited Book Chapters (published and In press): **12**

Books and Monographs: 5

Other Publications (includes publications in Internet): **11**

Awards to Staff in the Project

- **Franco Luis H.:** Outstanding Support Staff (OSSCA), CIAT, December 2003

- **Wenzl, P., A. L. Chaves, G. M. Patiño, J. E. Mayer and I. M. Rao.** 2002. Aluminum stress stimulates the accumulation of aluminum-detoxifying organic acids in root apices of *Brachiaria* species. J. Plant Nutrition and Soil Science 165: 582-588. Outstanding Research Publication Award (ORPA), CIAT, December 2003.

- **Reiber Christoph:** Ruthenberg-Preis 2004 Potential and constraints of cowpea (*Vigna unguiculata*) in Honduran hillsides. A farmers' assessment. Master-thesis, University of Hohenheim. Field work with CIAT in Honduras

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- **Pabón, A**., **G. Sotelo, and C. Cardona:** "Francisco Luis Gallego Award" to the best paper presented by an undergraduate student. XXX Congress of the Colombian Entomological Society, 2003.

3.0 Workshops / Conferences/Meetings (attendance by one or more staff of the Forage Project)

Event	Dates	Location
Workshops		
Priorities for PESA II – Project design workshop MAGFOR-FAO	12 February	Managua, Nicaragua
International Workshop on Adaptation to Climate Change, Sustainable Livelihoods and Biological Diversity	16-18 March	Turrialba, Costa Rica.
XXXI Congreso Sociedad Colombiana de Entomología (SOCOLEN)	28-30 July	Bogotá, Colombia
Generation Challenge Program Workshop on Phenotyping and Water Deficit held at Agropolis	5-9 July	Montpellier, France
The Ethiopian Agricultural Biotechnology Initiative	6-8 July	Addis Ababa, Ethiopia
XX Congreso Brasileiro de Entomología	5-10 September	Gramado, Brazil
II Seminario Internacional de Actualización en Medicina Veterinaria	17-18 September	Managua, Nicaragua
CGIAR Systemwide Livestock Program: Strategies for Targeting and Scaling out Fodder Innovations for Small-scale Farmers in Developing Countries	21-23 September	Hyderabad, India
FAO/gtz workshop: Effective Communication between Agricultural Research, Extension and Farmers	18-22 October	Laimburg, Italy
Meetings		
Formulación de una agenda de investigación para mejorar la alimentación de ganado bovino durante la estación seca	29 October, 2003	Managua, Nicaragua
Reunión de la Red Iberoamericana de Ganadería Sostenible	29-30 April	Barranquilla, Colombia
Meeting with Secretaría de Agricultura y Ganadería del Valle del Cauca, Colombia	29 April	CIAT
Technical committee BMZ funded project Demand-Driven Use of Forages in Fragile, Long Dry Season Environments of Central America to Improve Livelihoods of Smallholder	28 May	Managua, Nicaragua
Reunión Junta Directiva de CIAT	9-13 May	Corpoica-La Libertad, Villavicencio
Reunión Comité Técnico de la Iniciativa Amazónica	27 May-June 2	Iquitos, Perú
Meeting with Forage Group of EMBRAPA	9-12 August	Brasilia and Campo Grande, Brazil
Conferences		
III Congreso Nacional del Sector Lácteo	6-8 February	Matagalpa, Nicaragua
Annual meeting MIS consortium	03-05 March	Matagalpa, Nicaragua
Diversification in the coffee zone of Nicaragua (IICA-USAID)	05 March	Jinotega, Nicaragua
I National Congress on agricultural innovation – FUNICA	24-26 March	Managua, Nicaragua
Conference on Agronatura	2 March	CIAT
Visión Estratégica para la Cooperación CORPOICA-CIAT	29 April	CIAT
International Seminar: Oportunidades y retos de la ganadería colombiana frente a los acuerdos de libre comercio	5-6 August	Fedefondos, Bogotá
American Phytopathological Society Annual Meeting,	30 July-7 August	Anaheim, CA, USA
International Symposium on Frontier Research to Improve Crop productivity on Acid Soils held at Research Institute for Bioresources, Okayama.	31 July-5 August	University, Kurashiki, Japan
International Symposium on "Al Stress Research in Plants: Present Status and New Directions for Future". Satellite Symposium of the 6th PSILPH in Sendai. Research Institute for Bioresources	6-8 August	University, Kurashiki, Okayama, Japan
6th International Symposium on Plant-Soil Interactions at Low pH (PSILPH).	6-8 August	Japanese Society of Soil Science and Plant Nutrition, Sendai, Japan
Deutscher Tropentag	5-7 October	Berlin. Germany

4.0 Strengthening NARS

Training Events: Courses/Workshops /Field Days

Africa

Workshops

Event	Dates	Location	Participants		
			M	F	Total
Workshop on Participatory Research Concepts and Methods	13-17 October 2003	Debre Zeit, Ethiopia			NA
Monitoring and evaluation workshop	23-28 August	Kano, Nigeria			NA

Asia

FLSP (The Forage and Livestock System Project funded by AusAID for Laos): Number persons day: 14,796

Event	Dates	Location	Participants
Mid Season review workshop	20–24 October 2003	Xieng Khouang	32
Workshop on Poverty Alleviation and stabilization of Shifting Cultivation	27 – 30 January	Luang Phabang	2
Workshop on extension and field activities for 2004	10 February	Vientiane	7
Workshop on selection of forages for the tropics	11 – 16 February	Hanoi, Vietnam	1
Adoption Tree database training	22 – 26 February	Xieng Khouang	13
Adoption Tree database training	29 Feb – 03 Mar	Luang Phabang	22
Pre season review workshop	22 – 26 March 2004	Luang Phabang	32
Workshop on case study development	04 – 08 April 2004	Luang Phabang	17
Workshop on case study development	12 – 15 April 2004	Xieng Khouang	15
Workshop on methods for scaling-out impacts	05 – 09 May 2004	Xieng Khouang	14
Workshop on methods for scaling-out impacts	10 – 17 May 2004	Luang Phabang	17
Forages: Impacts and Options for upland farmers in Lao PDR	31 May 2004	Luang Phabang[1]	50
Forages: Impacts and Options for upland farmers in Lao PDR	07 June 2004	Savannakhet[1]	37
Workshop and field training on scaling-out impacts	09 – 18 July 2004	Luang Phabang	15

[1] These workshops were conducted in response to requests we received from development organizations that wanted to start their own forage and livestock programs with farmers. The participants represented 23 organizations, most of which started their own forage programs this year

LLSP (The Livelihood and Livestock Systems Project funded by ADB for seven countries in Asia): Number persons day: 12,285

Event	Dates	Location	No. participants		
			Male	Female	Total
Participatory livestock research and development training course (organized by PCARRD)	2-6 Jun 03	Small Ruminant Center, Central Luzon State University, Philippines	9	8	17
LLSP planning workshop and write-shop	23-27 Jun 03	Cagayan de Oro City, Philippines	18	11	29
Training course on forage selection and establishment	1-3 Sep 03	Animal Health and Production, Kampong Cham, Cambodia	10	3	13
Planning workshop with LLSP collaborators	4-5 Aug 03	Penajam, Indonesia	15	3	18
Cross visit of FLSP partners in Tuyen Quang	18-23 Aug 03	Tuyen Quang, Viet Nam	15	2	17
Training course on animal nutrition and experimentation with small farmers	23-26 Sep 03	BPLB, Sempaja, Indonesia	13	1	14
Training course on participatory diagnosis and evaluation	11-14 Nov 03	Kampong Cham, Cambodia	13	1	14
Cross visit of Tang Jun, Vu Hai Yen and Yacob Pangedongan to FLSP sites	22-29 Nov 03	Luang Phabang, Lao PDR	2	1	3
Livestock market study workshop	11-14 Dec 03	Ea Kar & M'Drak District, Viet Nam	38	25	63
Annual Review and planning workshop of LLSP Philippines	15-17 Dec 03	Cagayan de Oro City, Philippines	8	8	16
Training course on forage seed production for LLSP collaborators from Viet Nam	6-12 Oct 03	Mukdahan Animal Nutrition Station, Thailand	6	4	10
Dissemination methodology workshop	7-8 Jan 04	Tuyen Quang and Daklak Province, Viet Nam	9	3	12
Training course on developing forage technologies with small farmers	21 – 27 Jan 04	BPLP in Sempaja, Samarinda, Indonesia	12	3	15
Training course on production system analysis and planning workshop for field staff	15-19 Mar 04	East Kalimantan, Indonesia	8	2	10
Training course on enhancing skills in participatory research methods	6-10 Apr	CATAS, PR. China	20	2	22

In addition, LLSP project partners organized a large number of trainings, field days and cross visits for extension workers and farmers in the region.

LAC

Workshops: Number persons day: 9,010

Event	Dates	Location	Participants		
			M	F	Total
Common bean and *Brachiaria* improvement for acid soils Workshop	25-26 February	CIAT	28	5	33
Workshop: Trade-offs of livestock productivity and pasture degradation	15-18 March	Juticalpa, Honduras	32	3	35
Metodología de diagnóstico abierto en sistemas de alimentación de ganadería	17-27 May	Juticalpa, Honduras	14	1	15
Workshop: Taninos en la nutrición de rumiantes en Colombia	18 May	CIAT	12	27	39
Supply and demand of dry season feeding alternatives	8-13 August	Juticalpa, Honduras ad, Ocotal, Nicaragua	15		15
Workshop: Harinas de leguminosas para alimentación animal	13-14 September	CIAT	28	5	33

Training: Number persons day: 4,662

Event	Dates	Location	Participants		
			M	F	Total
Pasture management for INTA field staff	07 November, 2003	Sebaco, Nicaragua	28	0	28
Dry season feed strategies (FONDEAGRO)	12-14 November, 2003	Matiguás, Nicaragua	31	15	46
Seed production with farmers (FONDEAGRO)	10 December, 2003	Matiguás, Nicaragua	13	8	21
Curso sobre Forrajes a tecnicos de Semillano (Seed Company)	17-18 February	CIAT	6		6
Curso sobre forrajes a tecnicos de Coolechera (Milk Processing Cooperative)	26-27 February	CIAT	6	2	8
Cursos de capacitación en Establecimiento, Manejo y Utilización de Forrajes Henos y Ensilajes	20 February, 5 May, 2 and 9 June, and 7 July	Roldanillo, Valle, Colombia	19	8	25
Pasture management using electric fences + Seed market and availability in CA (FONDEAGRO)	19 March	Matiguás, Nicaragua	31	15	46
Metodología de diagnóstico abierto en sistemas de alimentación de ganadería	24-28 May	Ocotal, Nicaragua	10		10
Curso corto sobre forraje a miembros de la Sociedad de Agricultores y Ganaderos (SAG) del Valle, Colombia	6 September	CIAT	18		18
Cooperativa de Técnicos y Profesionales de Urabá Norte (ATUN)	7-8 September	CIAT	12	2	14

Field days: Number persons day: 2,915

Event	Dates	Location	Participants		
			M	F	Total
Germplasm and pasture management at SOL site, San Dionisio, for FAT field staff	10 October, 2003	San Dionisio, Nicaragua	12	0	12
Field visit COSUDE staff from Switzerland	20 February	San Dionisio, Nicaragua	3	0	3
Field visit of IDR project San Rafael del Norte, Jinotega	23 March	San Dionisio, Nicaragua	6	0	6
Legumes as possible cover crops in the first planting season (farmers from San Dionisio)	12 May	San Dionisio, Nicaragua	16	4	20
Arachis pintoi cv. Maní forrajero perenne. Una leguminosa para el Piedemonte llanero	July 3 June 26	San Martin and Villavicencio, Meta, Colombia	23 38	12 22	35 60
Field visit of CRS regional staff	21 June	San Dionisio, Nicaragua	3	0	3
Arachis pintoi. cv. Maní forrajero perenne. Alternativa de alimentación para el Piedemonte de los llanos	August 7 August 27	Guamal and Restrepo, Meta, Colombia	25 38	8 12	33 50
Legumes as possible cover crops in the second planting season (farmers from San Dionisio)	16 August	San Dionisio, Nicaragua	25	13	38
Field visit FUNDACION ODORICO, San Rafael del Norte, Jinotega	24 September	San Dionisio, Nicaragua	5		5

Conferences/Meetings: Number persons day: 86

Event	Dates	Location	Participants		
			M	F	Total
Revisión de la Cooperación CORPOICA-CIAT	29 April	CIAT	21	4	25
Alimentación de ganado durante la estación seca	23 June	Managua, Nicaragua	16	2	18

5.0 Thesis Students

BS Thesis

Name	Status	University	Title
Bertrand Ramón Iván	Completed	Universidad Católica Agropecuaria del Trópico Seco, Estelí, Nicaragua	Diagnóstico sobre alimentación de ganado doble propósito en época de verano en comunidades aledañas al municipio de Somoto, Madriz – Nicaragua
Chaves Q. Carlos A.	Completed	Universidad de Costa Rica, Costa Rica	Calidad y consumo de *Cratylia argentea* y sorgo forrajero (*Sorghum* sp.) con y sin melaza ensilada en bolsas plásticas
Flores Zenelia	Completed	Universidad Nacional Autónoma de Nicaragua – UNAN CUR, Matagalpa, Nicaragua	Determinación de la composición botánica, disponibilidad y producción de leche en potreros establecidos con pastos *Brachiaria* en asociación con *Arachis pintoi* en la comunidad Wibuse, San Dionisio
Abello Javier F.	On-going	Universidad Nacional, Bogotá, Colombia	*Brachiaria* endophytes as gene delivery system
Leiva Aráuz, Oscar Javier and Martínez González Róger	2005	Universidad Católica Agropecuaria del Trópico Seco, Estelí, Nicaragua	Validación de sistemas de cultivos con introducción de leguminosas como abonos verdes y coberturas sobre la sostenibilidad de sistemas de producción tradicionales en una microcuenca
Mera Álvarez Mónica Lorena	Completed	Universidad Nacional de Colombia, Palmira, Colombia	Efecto de leguminosas forrajeras tropicales ricas en taninos sobre la fermentación ruminal y la producción de metano en un sistema in vitro (RUSITEC)
Miller María Fernanda	On-going	Universidad del Valle, Cali, Colombia	Resistencia de *Brachiaria* spp. al salivazo*:* Efectos subletales de cultivares resistentes sobre los adultos de *Zulia carbonaria* (Lallemand) (Homoptera: Cercopidae)
Real Posada Franklin Rigoberto, Rayo Carazo Omar Antonio, Ramirez Ramirez Edwin José, Lopez Suarez Cheyla Matilde, Romero Duarte Juan Adán, Luna García Álvaro José	On-going	Universidad Nacional Agraria (UNA), Managua, Nicaragua	Survey on dry season feed resources in three different livestock regions of Nicaragua
Rincón Lozano Joisse Dayana	On-going	Universidad Nacional de Colombia, Palmira, Colombia	Evaluación del efecto de la sequia en genotipos de *Brachiaria* bajo condiciones de invernadero
Rosero Jaime	On-going	Universidad Nacional, Palmira	Ensayo Multilocacional de Sistemas de Establecimiento de *Cratylia argentea* cv. Veranera
Sotelo Paola	Completed	Universidad del Valle, Cali, Colombia	Resistencia de *Brachiaria* spp. al salivazo*:* Efectos subletales de cultivares resistentes sobre los adultos de *Aeneolamia varia* (F.) (Homoptera: Cercopidae)

MS Thesis

Name	Status	University	Title
Arango Adriana	Completed	National University, Bogotá, Colombia	Identification of candidate genes for aluminium resistance in *Brachiaria*
Castro Ulises	On-going	Colegio de Postgraduados de Chapingo, Chapingo, Mexico	Mechanisms of resistance to *Aeneolamia albofasciata* and *Prosapia simulans* en *Brachiaria* spp.
Cortés Cortés Javier Eduardo	On-going	Universidad Nacional de Colombia, Bogotá, Colombia	Efecto de los taninos de leguminosas tropicales sobre la degradación in vitro de la proteína con fluido ruminal y pepsina
Husselman Madeleen	On going	Wageningen Agricultural University	Evaluation of potential production of seed from the hybrid Brachiaria "Mulato" with small plot and on-farm trials on the Bolovens Plateau in southern Lao
Monsalve Castro Lina Maria	On-going	Universidad Nacional de Colombia, Palmira, Colombia	Efectos sobre la fermentación ruminal, el flujo de proteína duodenal y la absorción de nitrógeno en ovinos alimentados con leguminosas con y sin taninos
Nieto B. Juan C.	On-going	Universidad de Costa Rica, Costa Rica	Caracterización nutricional de material fresco y ensilado de Maní forrajero (*Arachis pintoi*) cultivado en asocio con Maíz (*Zea mays*) a tres densidades de siembra
Noto Fabio	Completed	Swiss Federal Institute of Technology (ETH), Zurich, Switzerland	Effects of provenance (Colombia and Kenya) on the ruminal fermentation characteristics of *Calliandra calothyrsus* (var. Patulul)
Pabón Alejandro	On-going	Universidad de Viçosa, Brazil	Mechanisms of resistance to *Deois incompleta* and *Notozulia entreriana* en *Brachiaria* spp.
Payan Arlen	On going	Centro Agronómico de Investigación y Enseñanza (CATIE), Costa Rica	Efecto de *Cratylia argentea* sobre la producción animal en la cuenca de Jucuapa, Matagalpa, Nicaragua
Reiber Christoph	Completed	University of Hohenheim	Potential and constraints of cowpea (*Vigna unguiculata*) in Honduran hillsides. A farmers' assessment.
Ricaurte José Jaumer	On-going	Universidad Nacional de Colombia, Palmira, Colombia	Impact of aluminium tolerant *Brachiaria* genotypes on soil quality characteristics of an oxisol of the altillanura of the Meta Department of Colombia
Stürm Christoph Dominic	Completed	Swiss Federal Institute of Technology (ETH), Zurich, Switzerland	Effects of combinations of legumes with contrasting contents of tannins on in vitro ruminal fermentation
Vivas Nelson	On-going	Universidad Nacional de Colombia, Palmira, Colombia	Evaluación agronómica de 144 accessiones de *Desmodium velutinum* como alternativa forrajera para las zonas de ladera del norte del departamento de Cauca

PhD Thesis

Name	Status	University	Title
Andersson Meike Stephanie	On-going	University of Hohenheim, Germany	Genetic diversity and core collection approaches in the multipurpose shrub legumes *Flemingia macrophylla* and *Cratylia argentea*
Bartl Karin	On-going	Swiss Federal Institute of Technology (ETH), Zurich, Switzerland	Effects of improved feeding systems for dairy cattle in tropical smallholder farms on milk production and quality at high altitudes
Castañeda Nelson	On-going	University of Goettingen, Germany	Genotypic variation in P acquisition and utilization in *Arachis pintoi*
Hernández Luis Alfredo	On going	University of Hohenheim, Germany	A participatory procedure applied to selection and development of forages with farmers
Louw-Gaume Annabé	On-going	ETH, Zurich, Switzerland	Adaptation of *Brachiaria* grasses to low P soils
Mejia Sergio	On-going	Universidad Nacional de Colombia, Palmira, Colombia	Identification of candidate genes responsible for adaptation of tropical forage grass, *Brachiaria* to low phosphorus soils
O'Brien Rachel	Completed	Curtin University, Australia	Incorporating socio-economic data and expert knowledge in complex spatial decision-making
Reiber Christoph	On going	University of Hohenheim, Germany	Encouraging adoption of research-based offerings with contrasting extension approaches
Rincon Alvaro	On-going	Universidad Nacional de Colombia, Bogotá, Colombia	Integration of maize with forages to recuperate degraded pastures in the Llanos of Colombia
Tiemann Tassilo	On going	Swiss Federal Institute of Technology (ETH), Zurich, Switzerland	The forage potential of tanniniferous legumes: Search for sustainable ways to cope with nutritional limitations in smallholder livestock
Tscherning, Karen Joanna	Completed	University of Hohenheim, Germany	Development of methods for the simultaneous evaluation of forage legume for feed and for soil improvement
Van der Hoek Rein	Completed	University of Hohenheim, Germany	Participatory research methods for forage-based technologies in Central-American hillsides

6.0 Resource Mobilization

Proposals and CN submitted

Title	Donor	Budget	Duration
Forage legume supplementation of village pigs in Laos	ACIAR	AUS$400k	3 years
Biocidal proteins from native African plants and microbes for control of plant diseases and pests of major economic importance	ASARECA Biotechnology competitive grant	US$150,000	
Bringing *Brachiaria* back home to Africa: reaching African farmers with high quality productive *Brachiaria* grasses bred and improved in Latin America	ASARECA, JICA or other donors	Not defined	
Improving phenotypic screening and functional genomics: Identification of genes and gene combinations responsible for resistance to aluminum and drought stress in rice and Brachiaria	CGIAR Challenge Program on Generation	US$898,570	3 years
Dinámica de las fuentes de inóculo y análisis de la estructura de las poblaciones de los agentes causales de la antracnosis en especies de frutales promisorios	Colciencias	$US108,000	3 years
Improving food security and resilience of production systems of drought prone hillside areas of Honduras	España – INIA - Honduras	US$337,680	36 months 2005-2007
Pasture Management Training for Field Staff	EU – Proyecto Norte	US$5,500	2 training modules
Realizing the benefits of underutilized legumes: Improving and diversifying production and enhancing soil quality in semiarid to sub-humid regions of Latin America (LATLEG)	EU-INCO	€178,700 (US$220,000)	2005-2007
Fortalecimiento de la capacidad educativa del CETA MuyMuy en tecnologías forrajeras	FONDEAGRO- Nicaragua	US$52,920	8 months 2004-2005
Introducción participativa de forrajes mejorados en sistemas de producción de leche de pequeños y medianos productores en Jinotega, Nicaragua	IICA-USAID - Nicaragua	US$41,140	19 months 2004-2005
Genetic Exploitation of Nitrification Inhibition in Crops and Pastures – A Novel Strategy to Minimize Nitrate Leaching and Nitrous Oxide Emissions from Agricultural Systems	New Energy and Industrial Technology Development Organization (NEDO), Japan	¥90 million	3 years
Highlighting available scientific data to address concerns related to modern biotechnology in the East African context	Program for Biosafety Systems (PBS): A Competitive Grants Program on Biotechnology and Biodiversity Interface (BBI)	US$277,200	
Capacity Building Project between the Lao National Agriculture and Forestry Research Institute (NAFRI) and CIAT		US$500,000	Expected to commence in January 2005

7.0 Partnerships with NARS, Universities, NGO's and Producer Associations

Enhancing beef productivity, quality, safety and trade in Central America (led by ILRI and funded by CFC): MAGA and ASOBRAHMAN, Guatemala; DICTA, FENAGH and SENASA, Honduras; MAG-FOR, IDR and FAGANIC, Nicaragua; CORFOGA, Costa Rica

Livelihoods and Livestock Systems Project: Chinese Academy of Tropical Agricultural Science (CATAS), Hainan, China; Provincial Livestock Services, Samarinda , East Kalimantan and Directorate General of Livestock Services (DGLS), Jakarta, Indonesia; National Agriculture and Forestry Research Institute, (NAFRI), Vientiane, Lao PDR; Philippine Council for Agriculture, Forestry and Natural Resources Research and Development (PCARRD), Los Baños, Philippines; Leyte State Universsity and Department of Agriculture, Region 10, Philippines; Department of Livestock Development, Ministry of Agriculture and Cooperatives, Bangkok, Thailand; National Institute of Animal Husbandry (NIAH), Ministry of Agriculture and Rural Development (MARD), Hanoi, Vietnam; Tay Nguyen University, Daklak, Vietnam; National Animal Health and Production Investigation Center, Department of Animal Health and Production, Phnom Penh, Cambodia.

Participatory evaluation improved forages in hillsides of Central America: DICTA, Honduras; INTA, FONDEAGRO, and Campos Verdes, Nicaragua; MAG, Fundacion Ecotropica, Costa Rica; SERTEDESO, Honduras

Potential utility of Mulato in intensive dairy systems in SE Asia: Papalotla and Participatory evaluation improved forages in Asia: Department of livestock development, Ministry of Agriculture, Bangkok, Thailand

Potential utility of Mulato in smallholder livestock systems of northern Laos: Papalotla and Forages and Livestock Systems Project: NAFRI, Laos

Validation and promotion of *Brachiaria* hybrid cv Mulato in LAC: CORPOICA, Colombia**,** IDIAP, Panama; MAG, Costa Rica; INTA and MAG-FOR, Nicaragua; and IDIAF, Dominican Republic, and Semillas Papalotla

Validation and promotion of *Brachiaria* hybrid cv Mulato seed production in SE Asia. The Pakchong Animal Nutrition Research Center in Thailand, The Khonkaen Nutrition Research Center, Thailand and Semillas Papalotla.

8.0 Partnerships with ARO's.

CSIRO and QDPI, Australia and ILRI, Kenya: Development of a database and retrieval system for the selection of tropical forages for farming systems in the tropics and subtropics (SoFT).

ETH, Zurich, Switzerland: a) Adaptation of *Brachiaria* to low P, b) Forage potential of tanniniferous legumes and c) Improved feeding systems for smallholder dairy cattle with emphasis on dry season feeding and its effect on milk production and quality.

Hokkaido University, Japan: Mechanisms of plant adaptation to acid soils.

New Zealand Ag Research, New Zealand: Endophytes in tropical grasses

U of Goettingen, Germany: Genotypic variation in *Arachis pintoi* for tolerance to low phosphorus

U of Hohenheim, Germany: Participatory evaluation of forages in hillsides of Central America; Evaluation of *Cratylia argentea*, *Flemingia macrophylla* and *Desmodium velutinum*

University of Kentucky, USA, Dept of Plant Pathology, Identification of alkaloid profiles in endophyte- infected *Brachiaria* tissues as well as in pure cultures

JIRCAS, Japan: Nitrification inhibition in tropical grasses

8.0 Impact Monitored

- **Sales/planting of *Brachiaria* hybrid cv Mulato:** As a result of a vigorous promotion by Papalotla and subsidiaries the sales of seed in LAC of cv Mulato during 2004 were greater than in 2003. In addition, new countries started purchasing seed of Mulato. The estimated area planted with Mulato is 49,000 ha. The distribution of sales per country is show bellow:

Country	**Seed Sold [1] (Kg)**		**Planted Area (estimated) [2] (Ha)**
	2003	**2004**	
Bolivia		600	150
Colombia	9,800	26,920	9,180
Costa Rica	1,400	2,250	913
El Salvador		2,000	500
Ecuador	2,500	5,900	2,100
Florida, US	2,200	11,155	3,339
Guatemala	4,700	10,000	3,675
Honduras	8,000	7,500	3,875
Mexico	32,644	44,511	19,289
Nicaragua	1,170	2,170	967
Panama	10,000	9,010	4,753
Total	**72,944**	**122,016**	**48,741**

[1] Source: Papalotla
[2] Assumes all seed planted at a rate of 4 kg/ha

Annex

List of Publications

Refereed Journal (published, In press and submitted):

Abreu, A.; Carulla J.E.; Kreuzer, M.; Lascano C.E.; Díaz T.E.; Cano A.; Hess H.D. 2003. Efecto del fruto, pericarpio y extracto semipurificado de saponinas de *Sapindus saponaria* sobre la fermentación ruminal y la metanogénesis *in vitro* en un sistema RUSITEC. Revista Colombiana de Ciencias Pecuarias, 16:147-154.

Abreu, A.; Carulla J.E.; Kreuzer, M.; Hess H.D.; Lascano C.E.; Díaz T.E. 2003. Evaluación del efecto del extracto de saponinas semipurificadas de *Sapindus saponaria* sobre la fermentación ruminal y la metanogénesis *in vitro* en un sistema RUSITEC. Revista de Investigaciones de la Universidad Nacional Abierta y a Distancia 2:105-114.

Amézquita, E.; Thomas, R. J.; Rao, I.M.; Molina, D.L.; Hoyos, P. 2004. Use of deep-rooted tropical pastures to build-up an arable layer through improved soil properties of an Oxisol in the Eastern Plains (Llanos Orientales) of Colombia. Agriculture, Ecosystems and Environment 103:269-277.

Begum, H. H.; Osaki M.; Nanamori M.; Watanabe T.; Shinano T.; Rao, I. M. 2004. Role of phosphoenolpyruvate carboxylase in the adaptation of a tropical forage grass, *Brachiaria* hybrid, to low phosphorus acid soils. Journal of Plant Nutrition (In review).

Cardona, C.; Fory P.; Sotelo G.; Pabon A.; Díaz G.; Miles, J. W. 2004. Antibiosis and tolerance to five species of spittlebug (Homoptera: Cercopidae) in *Brachiaria* spp.: Implications for breeding for resistance. J. Econ. Entomol. 97(2): 635-645.

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Chakraborty, S.; Ghosh, R.; Ghosh , M.; Fernandes, C. D.; Charchar, M. J.; Kelemu, S. 2004. Weather-based prediction of anthracnose severity using artificial neural network models. Plant Pathology 53:375 –386.

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Hess, H.D.; Lascano C.E.; Carulla, J.E.; Díaz, T.E.; Machmüller, A.; Kreuzer, M. 2003. Potential of forage legumes and of saponin-containing fruits as tropical feed resources to manipulate rumen fermentation and to improve ruminant nutrition. Tropical and Subtropical Agroecosystems 3: 555-559.

Hess, H.D.; Kreuzer, M.; Díaz, T.E.; Lascano, C.E.; Carulla, J.E.; Soliva, C.R.; Machmüller, A. 2003. Saponin rich tropical fruits affect fermentation and methanogenesis in faunated and defaunated rumen fluid. Animal Feed Science and Technology 109:79-94.

Hess H.D.; Valencia, F.L.; Monsalve, L.M.; Lascano, C.E; Kreuzer, M. 2004. Effects of tannins in *Calliandra calothyrsus* and supplemental molasses on ruminal fermentation *in vitro*. Journal of Animal and Feed Science 13(Supp1):95-98.

Hess, H.D.; Beuret, R.A.; Lötscher, M.; Hindrichsen, I. K.; Machmüller, A.; Carulla, J.E.; Lascano, C. E.; Kreuzer, M. 2004. Ruminal fermentation, methanogenesis and nitrogen utilization of sheep receiving tropical grass hay-concentrate diets offered with *Sapindus saponia* fruits and *Cratylia argentea* foliage. Animal Science 79:177-189.

Holmann, F.; Rivas, L.; Argel, P.; Pérez, E. 2004. Impact from the adoption of grasses from the *Brachiaria* genus on productivity and income of livestock producers: A case study of Central America and Mexico. Journal of Livestock Research for Rural Development (submitted).

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Ishikawa, T.; Subbarao, G.V.; Ito, O.; Okada, K. 2003. Suppression of nitrification and nitrous oxide emission by the tropical grass *Brachiaria humidicola*. Plant and Soil 255:413-419.

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O'Brien, R.; Peters, M.; Schmidt, A.; Cook, S.; Corner, R. 2004. Helping farmers select forage species in Central America: the case for a decision support system. Agriculture Ecosystems and Environment. (submitted).

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Peck, D. C.; Rodriguez, J.; Gómez, L. A. 2004. Identity and first record of the spittlebug *Mahanarva bipars* (Hemiptera: Auchenorrhyncha: Cercopidae) on sugarcane in Colombia. Florida Entomologist. 87(1): 82-84.

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Peters, M.; Hyman, G.; Jones P. 2004. Identifying areas for field conservation of forages in disturbed environments. Ecology and Society, (In press).

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