

Tropical Grasses and Legumes: Optimizing genetic diversity for multipurpose use

Executive Summary

Annual Report 2005

IP5 Project



SUMMARY ANNUAL REPORT 2005

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

Project Description and Log Frame

1.1 IP5: Tropical Grasses and Legumes: Optimizing Genetic Diversity for Multipurpose use (Project Manager: Carlos E. Lascano)

Goal: To improve the livelihoods of poor rural livestock communities and contribute to greater access of poor urban consumers to high and safe quality animal products by strengthening forage-based feeding systems while taking advantage of the potential of forages to enhance natural resource management and provide environmental services

Objective: To develop and disseminate improved forage-based technologies to enhance productivity, profitability and sustainability of smallholder crop/livestock systems in tropical areas of both low and high potential

External Conditions: Livestock development is key for alleviating poverty given that livestock are an important part of the livelihoods of many small farmers and that high growth in demand for animal products in developing countries is expected. However, a large proportion of the land in the humid and sub-humid tropics that supports smallholder crop/livestock systems is in different stages of degradation, which leads to low productivity, deforestation and poverty. In addition, resource-poor farmers in these regions have shortage of labor to collect feed from forest or wastelands and as a consequence livestock intensification is severely limited. Thus, restricted access to feed resources is a growing constraint for many poor livestock producers in tropical regions. Development and dissemination of improved forage technologies can improve livelihoods of small livestock producers while contributing to forest conservation, to the restoration of degraded agricultural land and to more abundant, cheaper, and safer high quality animal products for rural and poor urban consumers.

Important Assumptions: 1) International and national policies as well as livestock services are directed to favor small-scale producers to allow them to link to commodity markets; 2) Resources (unrestricted and restricted core) are identified to support Forage R&D in LAC, SE Asia and Africa; 3) The alliance with private forage seed companies continues to be strong to facilitate diffusion and adoption of improved forage cultivars.

Target Ecoregions: Tropical grasses and legumes being developed at CIAT are targeted to three main agroecological zones in the tropics: Savannas, Forest Margins and Hillsides/Uplands. These agro-ecosystems 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). A common constraint across the three targeted agro-ecosystems is low quantity and quality of forage biomass available to feed livestock (ruminants and non-ruminants); as a result animal production and productivity is low and environmental degradation is high.

Beneficiaries and End Users: Researchers from NARS, governmental and non-governmental development programs, private seed companies and small and large farmers throughout the sub-humid and humid tropics who need additional grass and legume genetic resources with high potential to intensify and sustain productivity of agricultural and livestock systems.

Collaborators: **Australia:** QDPI, CSIRO and Curtin University; **Brazil:** EMBRAPA; **Cambodia:** NAHPIC; **China:** South China University and CATAS; **Colombia:** Universidad de Sucre, REVERDECER, Universidad Nacional de Colombia-Palmira, Universidad de la Amazonía, CORPOICA, FIDAR, Universidad Nacional de Colombia-Bogotá, Universidad de los Llanos and

Fundación Universitaria San Martín; **Costa Rica:** UCR, MAG, Corporación de Fomento Ganadero, ECAG and CATIE; **Uganda:** African Highland Initiative and National Agricultural Research Organisation (NARO); **Ethiopia:** Areka Agricultural Research Institute, FARM Africa, International Livestock Research Institute (ILRI), Land-O-Lakes, Melkassa Agricultural Research Center and EARO; **Germany:** University of Goettingen, University of Hohenheim and University of Hannover; **Guatemala:** Asociación de Criaderos de Ganado Brahman and MAGA; **Honduras:** DICTA, FENAGH, GTZ and SERTEDESO; **India:** ILRI and ICRISAT; **Japan:** JIRCAS, Jikkaido University and National Grassland Research Institute; **Kenya:** ILRI, IFDC-CIMMYT and ICRAF; **Lao, PDR:** NAFRI and NAFE; **Malawi:** Department of Agricultural Research Service (DARS); **Mexico:** Semillas Papalotla and INIFAP; **Nicaragua:** INTA, MAG-FOR, FAGANIC, and Asociación Campos Verdes; **Nigeria:** IITA; **Philippines:** PCARRD and ViSCA; **Switzerland:** ETH; **Thailand:** DLD, PCANRC; **United States:** University of Kentucky and Rutgers University; **Vietnam:** NIAH and DARD

Project Changes: Since the last MTP 2004-2007, the Tropical Forage Project modified the goal and purpose.

Previous Goal: 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

Comment: As written the goal placed too much emphasis on milk and beef when increasingly we are working on other kinds of livestock (such as monogastrics) and other kinds of benefits (such as freeing up labor) that improve poor farmers welfare and contribute to lower price of animal products for poor rural and urban consumers.

New Goal: To improve the livelihoods of poor rural livestock communities and contribute to greater access of poor urban consumers to high and safe quality animal products by strengthening forage-based feeding systems while taking advantage of the potential of forages to enhance natural resource management and provide environmental services

Previous Objective: To develop and deliver to farmers superior gene pools of grasses and legumes for sustainable agriculture systems in sub-humid and humid tropics.

Comment: The objective as written implied that we are only involved in development and transfer of new forage cultivars. Increasingly we are working on the development of forage-based technologies that benefit livestock farmers (such as seed delivery system, or adding value to forage through processing) in areas of low and high potential for development of small holder livestock enterprises.

New Objective: To develop and disseminate improved forage-based technologies to enhance productivity, profitability and sustainability of smallholder crop/livestock systems in tropical areas of both low and high potential.

1.2 Project IP- 5: Log-Frame (MTP 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
<p>Goal</p> <p>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</p>	<ul style="list-style-type: none"> • 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 	<p>Statistics and case studies on socio-economic benefits and natural resource conservation in smallholder livestock farms in the subhumid and humid tropics</p>	<p>Policies are put in place by governments to favor sustainable livestock and forage development in marginal areas occupied by small farmers</p>
<p>Purpose</p> <p>To identify and deliver to farmers superior gene pools of grasses and legumes for sustainable crops-livestock systems in subhumid and humid tropics.</p>	<ul style="list-style-type: none"> • 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 	<ul style="list-style-type: none"> • Range of genetic variation in desirable plant traits • Performance of forage components in systems 	<ul style="list-style-type: none"> • Support from traditional and nontraditional donors • Effective collaboration: <ul style="list-style-type: none"> • CIAT's Projects • ARO's, partners and farmers, NGOs
<p>Outputs</p> <p>1. Grass and legume genotypes with high forage quality attributes are developed.</p>	<ul style="list-style-type: none"> • Determined the utility of legume mixtures for increasing protein supply in ruminants while reducing methane emissions 20% by 2005 • Selected at least 10 <i>Brachiaria</i> hybrids (sexual) 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 	<ul style="list-style-type: none"> • Demonstrated differences under field conditions <ul style="list-style-type: none"> • Scientific publications • Annual Reports • Theses 	<ul style="list-style-type: none"> • Effective collaboration with CIAT Projects (PE-2), AROs, partners and farmer groups
<p>2. Grass and legume genotypes with known reaction to pests and diseases and interaction with symbiont organisms are developed.</p>	<ul style="list-style-type: none"> • Validated a rapid screening method, with a capacity to evaluate 1000 genotypes in five days, to assess <i>Rhizoctonia</i> resistance in <i>Brachiaria</i> by 2005. • At least 10 <i>Brachiaria</i> 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 <i>Brachiaria</i> genetic recombinants with resistance to <i>Rhizoctonia</i> are available for regional testing in Central/South America by 2007. 	<ul style="list-style-type: none"> • Demonstrated differences under field conditions • Scientific publications • Annual Reports • Theses 	<ul style="list-style-type: none"> • Effective collaboration with CIAT Projects (SB-1, SB-2), AROs, partners and farmer groups

NARRATIVE SUMMARY	MEASURABLE INDICATORS	MEANS OF VERIFICATION	IMPORTANT ASSUMPTIONS
<p>3. Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed.</p>	<ul style="list-style-type: none"> • 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 <i>Brachiaria</i> 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 <i>Brachiaria</i> hybrids by 2007 	<ul style="list-style-type: none"> • Demonstrated differences under field conditions <ul style="list-style-type: none"> • Scientific publications • Annual Reports • Theses 	<ul style="list-style-type: none"> • Effective collaboration with CIAT Projects (SB-1, PE-2, PE-4), AROs, partners, NGOs and farmer groups
<p>4. In partnership with NARS, superior and diverse grasses and legumes are evaluated and disseminated through participatory research.</p>	<ul style="list-style-type: none"> • New market opportunities for processed forages assessed through surveys to at least 100 farmers with and without livestock in Honduras and Nicaragua by 2005 • <i>Brachiaria brizantha</i> 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 <i>Brachiaria</i> 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. 	<ul style="list-style-type: none"> • Promotional publication <ul style="list-style-type: none"> • Newsletters • Journal • Extension booklets • Surveys on adoption impact of new grasses and legumes: <ul style="list-style-type: none"> • Seed sold • Area planted • Production parameters • Environmental/socioeconomic indicators 	<ul style="list-style-type: none"> • Effective collaboration with CIAT Projects (PE-2, SN-1, SN-2, SN-3, BP-1 and Ecoregional Program), partners, NGOs and farmer groups

2. Output Targets reported to the CGIAR-Science Council in 2005

Output	Output Targets 2005	Category of Output Targets	Achieved?
Grass and legume genotypes with high forage quality attributes are developed	<ul style="list-style-type: none"> Developed and validated a methodology to screen <i>Brachiaria</i> hybrids for forage quality using NIRS (near-infrared reflectance spectroscopy) The use of mixtures of legumes with and without tannins decrease apparent ruminal protein degradation by 50-60% and increase 3-4 fold the proportion of dietary crude protein digested by acid-pepsin incubation 	Practice Practice	Achieved
Grass and legume genotypes with known reaction to pests and diseases and interaction with symbiont organisms are developed	<ul style="list-style-type: none"> Developed a screening method that combines laboratory and field selection with capacity to evaluate 1000 genotypes for resistance to <i>Rhizoctonia</i> in <i>Brachiaria</i>. Selected hybrids (4) with high levels of resistance Selected apomictic <i>Brachiaria</i> hybrids (6) with resistance to 5 species of spittlebug present in Colombia 	Practice Material	Achieved
Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed	<ul style="list-style-type: none"> Developed and validated a high-throughput method to screen <i>Brachiaria</i> hybrids for adaptation to low fertility acid soils Selected accessions (2) of <i>Desmodium velutinum</i> with high forage yield and quality in the wet and dry season 	Practice Material	Achieved
In partnership with NARS, superior and diverse grasses and legumes are evaluated and disseminated through participatory research	<ul style="list-style-type: none"> Household impact demonstrated through improved forages in Lao PDR. More than 1300 farmers in 106 villages (covering 5 districts in 2 provinces) adopt planted forages for livestock feeding. A total of 900 farmers benefit from improved forages: labor saving, improved animal production and increased household income Expert system for targeting forages -Selection of forages for the tropics (SoFT)- is released 	Practice Material	Achieved

3. Research Highlights 2005

Output 1: Grass and legume genotypes with high forage quality are developed

- **Validated a methodology to screen for quality large number of *Brachiaria* hybrids using NIRS**

Results from this year confirm that it is possible to detect with NIRS differences in crude protein (CP) and in vitro dry matter digestibility (IVDMD) among entries in a population of *Brachiaria* hybrids. Significant genetic variation among hybrid clones was detected for both IVDMD and CP. Large variation among sampling dates was also detected (for IVDMD, mean square = 7.9 vs. 878.8 for genotypes or sampling dates, respectively; for CP, mean square = 6.9 vs. 1,716.0 for genotypes or sampling dates, respectively). However, it is encouraging that despite the large effect of sampling date on both quality parameters, the interaction of genotype with sampling, while statistically significant, was less than that for genotypes (for IVDMD, mean square = 7.9 vs. 1.8 for genotypes or genotype-sampling date interaction, respectively; for CP, mean square = 6.9 vs. 2.6 for genotypes or genotype-sampling date interaction, respectively). Hence, it appears that sampling field-grown plants even on only a single date should be effective in identifying *Brachiaria* genotypes superior for quality traits.

- **Demonstrated the potential benefits of mixtures of legumes with and without tannins on nitrogen utilization by ruminants using an *in vitro* fermentation system**

Results from *in vitro* studies using a rumen simulation technique had shown that supplementation of low quality grasses with tannin-rich legumes decreases ruminal protein degradation. However, it is likely that such a decrease would result in a greater flow of dietary N to the lower digestive tract of ruminants feed tannin-rich legumes. This year, our work focused on the assessment of the potential acid-pepsin digestibility of rumen-undegradable protein from grass-based diets supplemented with legumes with and without tannins. Results showed that in mixed diets based on a low-quality grass, the replacement of *Cratylia argentea*, a legume without detectable amounts of tannins, by the tanniniferous *C. calothyrsus* (CIAT 22310) decreased apparent ruminal crude protein degradation by 65% (from 884 to 576 mg/g) and increased almost 4 fold (from 70 to 272 mg/g of N supplied) the proportion of dietary crude protein digested by acid-pepsin incubation. If these results are validated *in vivo*, the use of mixtures of legumes with and without tannins could effectively improve the supply of available protein in ruminants fed low quality grasses.

Output 2: Grass and legume genotypes with known reaction to pests and diseases and to interaction with symbiont organisms are developed

- **Selected apomictic and sexual *Brachiaria* hybrids with multiple resistance to spittlebug**

We continued to make significant progress in incorporating resistance to spittlebug in the *Brachiaria* improvement program using a recurrent selection scheme. In 2004 we reported varying levels of resistance to *Prosapia simulans* (one of the most important species affecting *Brachiaria* in Mexico) in 34 apomictic hybrids. These hybrids had been pre-selected in Mexico for good adaptation and desirable agronomic characteristics. A series of replicated tests were carried out in 2005 to evaluate the resistance of these genotypes to *Prosapia simulans* and to four major species of spittlebug present in Colombia (*A. varia*, *A. reducta*, *Z. carbonaria*, and *Mahanarva trifissa*). A total of 6 (18%) apomictic hybrids were selected for having resistance to all 5 species of spittlebug. In addition, this year 565 new sexual hybrids were tested for resistance to three spittlebug species and results showed that 96.2%, 94.7% and 93.9% were rated as resistant to *A. varia*, *A. reducta*, and *Z. carbonaria*, respectively.

- **Validated a field method to screen *Brachiaria* hybrids for *Rhizoctonia* foliar blight and found hybrids with high levels of resistance**

Rhizoctonia foliar blight is a disease of increasing importance in *Brachiaria* pastures in humid areas. The disease can be very destructive when environmental conditions are particularly conducive (high relative humidity, dense foliar growth, high nitrogen fertilization, and extended wet periods). A field experiment was carried out in 2005 to screen 137 *Brachiaria* genotypes for resistance to *Rhizoctonia*. Six plants of each of the *Brachiaria* genotypes were transplanted from a CIAT glasshouse to a field site in the Amazon of Colombia. Plants were inoculated one month after transplanting and evaluated for disease reaction using a 0 – 5 visual scale. Disease symptoms developed fully in susceptible genotypes 10-15 days after inoculations. There was a high degree of correlation in disease scoring among the various evaluation dates. The resistant control CIAT 16320 and four *Brachiaria* hybrids (BR04- 2577, BR04-2557, BR04-2983, and BR04-1214) showed less than 6% overall plant tissue damage, and thus, a high-level of resistance to the disease.

Output 3: Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed

- **Developed and validated a high-throughput method to screen *Brachiaria* hybrids for adaptation to low fertility acid soils**

A hydroponic screening method using stem cuttings was developed to quantify two key traits associated with adaptation to acid-infertile soils: root vigor and Al resistance. The vigor of root growth under nutrient deprivation influences plant adaptation to a range of nutrient deficiencies given that that nutrient acquisition relies on soil foraging, particularly in the case of immobile nutrients such as phosphorous. Al toxicity was targeted for selection because previous research showed genetic variability for this trait among *Brachiaria* species. Using the hydroponic screening method, 9 *Brachiaria* hybrids (out of a preselected population of 139 apomictic/sexual) were superior to *B. decumbens* cv Basilisk (parent in the breeding program and selected for superior adaptation to acid-infertile soils) in terms of root length in the presence of toxic level of Al. Among the 9 selected hybrids, one (BR04NO2681) was superior to *B. decumbens* cv Basilisk in terms of fine root development (lower root diameter), which is an indication of superior adaptation to low nutrient availability in soil.

- **Developed and tested greenhouse methodologies to screen *Brachiaria* hybrids for drought tolerance and adaptation to poorly drained soils**

A major objective of the *Brachiaria* improvement program is to develop genotypes that combine resistance to biotic constraints with adaptation to abiotic stresses such as drought and poorly drained soils. This year progress was made in the development of a greenhouse method to screen for drought tolerance based on root development and leaf expansion. Contrasting genotypes (16) of *Brachiaria* planted in transparent plastic cylinders filled with a mix of sandy-loam Oxisol with sand (2:1 w/w) were subjected to two levels of water supply (50% and 100% field capacity). The method used allowed to observe after 45 days of growth significant variation among checks and hybrids of *Brachiaria* in dry matter distribution, specific leaf area and root attributes due to drought stress (50% field capacity). Progress was also made in developing a method to screen *Brachiaria* genotypes for adaptation to waterlogging using small pots. Contrasting genotypes (23) were subjected to two treatments: control at field capacity and excessive water supply (5 cm over soil surface). The test allowed the selection based on green leaf biomass of genotypes that are known to perform well in poorly drained soils (*B.*

humidicola CIAT 679 and 6133 and *B. brizantha* cv Toledo). One *Brachiaria* hybrid (BR02NO1245) was markedly superior in its tolerance to waterlogging than the other hybrids, suggesting that there is scope to select for this trait in the *Brachiaria* improvement program.

- **Characterized diversity in the shrub legume *Desmodium velutinum***

Selection of tropical shrub legumes adapted to acid soils and with high forage quality is of high priority for development of improved feeding systems. Species such as *Desmodium velutinum* may be an alternative feed resource for intensive dairy system given its high nutritive value. However, most of the information available on *D. velutinum* is restricted to few accessions. A total of 137 accessions classified in three groups based on growth habit (erect, semi-erect and prostrate) are being evaluated in an acid low fertility site. Large variation in forage yield in the wet season was observed for accessions in the erect (142-297 g DM/plant) and semi-erect (112-246 g DM/plant) groups and less for accession on the prostrate (104- 130 g DM/plant) group. Variation in forage yield was also observed in the dry season. Forage quality in the high yielding accessions varied (IVDMD: 64- 73% and CP: 19- 22%) among accessions. These results indicate that there is scope for selecting high yielding and high quality accessions of *D. velutinum* for use in intensive livestock systems.

Output 4: Superior and diverse grasses and legumes delivered to NARS partners are evaluated and released

- **Significant household impact was achieved through improved forages in Lao PDR**

The Forages and Livestock Systems Project (FLSP) in Laos, funded by the Australian Agency for International Development (AusAID) was completed in June 2005. The project achieved its targets of developing and disseminating forage technologies to smallholder farmers, resulting in significant household impacts. More than 1300 farmers in 106 villages (covering 5 districts in 2 provinces) had adopted planted forages for livestock feeding. A total of 900 farmers were benefiting from significant impacts such as labor saving, improved animal production and increased household income. More than 150 farmers report they have been able to reduce or stop shifting cultivation as a direct result of intensifying their livestock production. More than 200 farmers report that intensifying their livestock production systems has allowed their children to attend school. The technologies deployed by this project and the approaches of working with farmers to achieve adoption has attracted considerable interest by large development projects, NGOs and the donor community in Laos, and have been incorporated into several project as a major component.

- **Demand and benefits of forage conservation technologies in Central America was documented as part of a pilot study**

Feed shortage during 5-6 months dry season severely limits livestock production and farm income in the subhumid areas of Central America. The Forage Program of CIAT has developed and promoted improved grass and legume species suitable for grazing, cut/carry systems and silage and hay production. In addition we have been working on adapting silage technologies to smallholder systems. Through independent surveys we documented this year the potential demand and benefits to smallholders of silage and hay for dry season feeding. Results indicate that feeding silage or hay to milking cows is profitable and that the benefit can be greater for small scale farmers than for large scale farmers. Plastic bag silage offers a low cost opportunity for small scale farmers, but the non-availability and high cost of suitable bags are seen as constraints for further uptake. An emerging market for hay was found in Costa Rica and to a lesser extent in Honduras. Farmers also saw a market opportunity for plastic bag silage.

- **Expert system for targeting forages -Selection of forages for the tropics (SoFT)- was released**

Forage research over the last 50 years has identified many tropical grasses and legumes that have a role in farming systems in developed and developing countries. Information on the adaptation and use of these species resides in peer-reviewed literature and research reports with limited distribution and, often most importantly, in the memories of forage agronomists with decades of experience of working with a wide range of forages in diverse farming systems. To address these deficiencies in knowledge sharing an inter- institutional (CIAT, CSIRO, QDPI, ILRI and the U of Hohenheim) project funded by ACIAR, Australia was setup to develop a knowledge system for the identification of forages suitable for specified niches within smallholder farming systems in the tropics and subtropics. The main features of the data base are: a) information in fact sheets on the adaptation, uses and management of forage species, cultivars and elite accessions, b) a selection tool built on LUCID™ that enables easy identification of best-bet species, c) bibliography of more than 6,000 references and abstracts on forage diversity, management and use which enable users with poor library facilities to access summaries of some of the key literature, d) global maps of climate adaptation for each species and e) a collection of photographs and images of species to help in their identification and use. The tool was officially released at the XXth International Grassland Congress in Ireland in June 2005. The database is now freely available on the Internet (www.tropicalforages.info) and on CD. Since the release there has been a steady increase in the number of visits in the internet site from 249 in June to 4810 in October.

4. Performance Indicators- List of Publications (see Annex)

Journal Articles in Refereed Journals (Published, In press and Submitted):	31
Articles in Non-Refereed Journals and Working Documents:	7
Monographs, Books and Book Chapters:	11
Articles and Abstracts in Proceedings:	56
Publications in Internet:	2
Technical Bulletins:	4

5. Special Projects/Donors contracts

5.1 On-going Special Projects in 2005

Title	Donor	Annual Budget (US dollars)	Duration
Proposals being funded or approved			
Adaptation of <i>Brachiaria</i> grasses to Low-P Soils	ZIL/ETH Switzerland	36,600	2003-2006
Demand-Driven Use of Forages in Fragile, Long Dry Season Environments of Central America to Improve Livelihoods of Smallholders	German Agency for Technical Cooperation	132,600	2004-2007
Development of a database and retrieval system for the selection of tropical forages for farming systems in the tropics and subtropics	ACIAR, BMZ, DFID	86,000	2002-2005
Development of low input systems such as organic farming by optimizing the use of legumes in a dry region of Nicaragua to strengthen soil fertility, yield, human nutrition and farm income. Use of legumes in low input systems (ULLIS)	KEF Commission for Development Studies at the Austrian Academy of Sciences	12,000	2005-2007
Enhancing Beef Productivity, Quality, Safety and Trade in Central America	ILRI	71,000	2003-2007
Genetic Improvement of <i>Brachiaria</i>	Papalotla	326,000	2001-2010
Improving Livelihoods Upland Farmers using Participatory Approaches to Develop more Efficient Livestock System.	Asian Development Bank	304,600	2003-2005
Jump-Starting Smallholder Farmer Participation in Public-Private Partnerships: Adapting Legume Forages for On-Farm Monogastric Production and the Feed Industry.	SLP-ILRI	48,400	2005-2006
PostDoc project Understanding and Catalyzing Learning Selection processes	BMZ	76,280	2005-2008
Research and development of multipurpose forage legumes for smallholder crop-livestock systems in the hillsides of Latin America	Volkswagen Foundation	7,200	2004-2006
The Forage potential of tannineferous legumes: Search for sustainable ways to cope with nutritional limitations in smallholder livestock systems	ZIL/ETH Switzerland	24,400	2003-2006

5.2 New Proposals approved in 2005 (or early 2006)

Title	Donor	Annual Budget (US dollars)	Duration
Fighting drought and aluminum toxicity: Integrating functional genomics, phenotypic screening and participatory evaluation with farmers to develop stress resistant common bean and <i>Brachiaria</i> for the tropics	BMZ	559,000	2006-2008
Forage legumes for supplementing village pigs in Lao PDR	ACIAR	295,000	2006-2008
Overcoming land degradation to mitigate deforestation in the humid tropics	PDF- GEF-UNEP	700,000	2006-2007

5.3 Proposals submitted in 2005 (under review)

Title	Donor	Total Budget (US dollars)	Duration
Mejoramiento de la Calidad de Vida de Agricultores bajo Riesgo: Tecnologías y Políticas para Rehabilitar Tierras Degradadas en Cultivos y Pastos en Nicaragua. Prepared with the Watershed, TSBF- LAC, Agroecosystems, and Forage	CIDA- Canada through the Nicaragua Office	8.7 million	5 years
Integration of Under-utilised Legumes in Crop-Livestock Systems for Improving Livelihoods of Resource-poor Farmers in Semiarid Latin America (Neglected legumes) (Joint proposal ETH, INRA, U of Goettingen Universities and NARS from Argentina, Brazil, Chile, Mexico and Nicaragua-MIS	EU	2.4 million	4 years
Utilization of High quality forage legumes: Improving social, economic, and environmental sustainability of crop-livestock systems of poor farmers in Nicaragua. Prepared with the TSBF- LAC Group	BMF, Austria	598,000.	3 years
Interacción entre el Estado de Nutrición de la Planta y los Atributos de Calidad Forrajera de Gramineas Tropicales. Prepared with the TSBF- LAC Group and the U. Nacional, Palmira, Colombia	COLCIENCIAS	220,000	3 years
Integrating legume cover crops to reverse soil degradation and improve nutrient supply in agro-ecosystems of the hillsides of Central America	Swiss National Science Foundation	176,000	3 years
Bringing <i>Brachiaria</i> back home: Reaching African farmers with high performance <i>Brachiaria</i> grasses developed in Latin America.	AfDB	3 million	5 years

5.4 Proposals submitted during 2005 (not approved)

Title	Donor	Total Budget (US dollars)	Duration
Rehabilitación de pasturas degradadas en fincas ganaderas para aumentar la competitividad de los sistemas de producción de leche en la región Caribe. Prepared with the Soils Group of CIAT and staff from CORPOICA. Currently being reconsidered by the MADR as indicated in recent meeting by the vice-Minister of Agriculture.	MADR	630,000.	3 years
Enhancing smallholder livelihoods in the tropics: Improving feed value of crop residues and sustainability of maize production through the use of multi-purpose legumes in crop-livestock systems in Central America and Southern Africa. Prepared with TSBF- Africa and CYMMT and submitted to the Competitive Research Grant Program.	SLP – ILRI	350,000	3 years

6. Capacity Building

6.1 Lists of undergraduate students supervised

Internship			
Name	Status	University	Title
Schoonhoven, Diane	Completed	Wageningen University, Holland	Estimation and comparison of benefits due to feeding silage and hay during the dry season on commercial dual-purpose cattle production systems in Honduras and Costa Rica
Zöfel, Katrin	Completed	University of Hohenheim, Germany	Morphological and phenological characterization and analysis of origin information of a collection of <i>Leucaena diversifolia</i>

BS Thesis			
Name	Status	University	Title
Abello Javier F.	Completed	Universidad Nacional, Bogotá, Colombia	<i>Brachiaria</i> endophytes as gene delivery system
Betancourth Martha	On-going	Universidad Nacional, Palmira, Colombia	Evaluación de la producción de leche con <i>Brachiaria</i> (Toledo y dos híbridos Mulato y Mulato 2) en suelos ácidos
Miller María Fernanda	Completed	Universidad del Valle, Cali, Colombia	Resistencia de <i>Brachiaria</i> spp. al salivazo: Efectos subletales de cultivos resistentes sobre los adultos de <i>Zulia carbonaria</i> (Lallemand) (Homoptera: Cercopidae)

BS Thesis

Name	Status	University	Title
Real Posada Franklin Rigoberto, Rayo Carazo Omar Antonio Ramírez Edwin José López Suárez 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	Completed	Universidad Nacional de Colombia, Palmira, Colombia	Evaluación del efecto de la sequía en genotipos de <i>Brachiaria</i> bajo condiciones de invernadero
Rosero Jaime	Completed	Universidad Nacional, Palmira	Ensayo Multilocacional de Sistemas de Establecimiento de <i>Cratylia argentea</i> cv. Veranera
Schöber Johanna	On-going		Literature review of <i>Pueraria phaseoloides</i> (in progress)

6.2 List of MS students supervised

Name	Status	University	Title
Atzmanstorfer Karl	On-going	University of Salzburg, Austria	2006. Semi commercial production of cowpea in Cauca and Valle
Castro Ulises	On-going	Colegio de Postgraduados de Chapingo, Chapingo, Mexico	Mechanisms of resistance to <i>Aeneolamia albofasciata</i> and <i>Prosapia simulans</i> en <i>Brachiaria</i> 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 <i>Brachiaria</i> "Mulato" with small plot and on-farm trials on the Bolovens Plateau in southern Lao
Hernández Chaves Moisés	Completed	University of Costa Rica	Evaluación de la selectividad de herbicidas y el control de malezas durante la fase de establecimiento de los pastos <i>Panicum maximum</i> , <i>Brachiaria brizantha</i> y <i>B. decumbens</i>
López Francisco	On-going	Universidad del Valle	Caracterización de la tolerancia al daño causado por adultos como componente de resistencia a <i>Aeneolamia varia</i> (F.) en genotipos de <i>Brachiaria</i> spp
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

Name	Status	University	Title
Nieto B. Juan C.	Completed	Universidad de Costa Rica, Costa Rica	Caracterización nutricional de material fresco y ensilado de Maní forrajero (<i>Arachis pintoi</i>) cultivado en asocio con Maíz (<i>Zea mays</i>) a tres densidades de siembra
Pabón Alejandro	On-going	Universidad de Viçosa, Brazil	Mechanisms of resistance to <i>Deois incompleta</i> and <i>Notozulia entreriana</i> en <i>Brachiaria</i> spp.
Payan Arlen	On-going	Centro Agronómico de Investigación y Enseñanza (CATIE), Costa Rica	Efecto de <i>Cratylia argentea</i> sobre la producción animal en la cuenca de Jucuapa, Matagalpa, Nicaragua
Ricaurte José Jaumer	On-going	Universidad Nacional de Colombia, Palmira, Colombia	Impact of aluminum tolerant <i>Brachiaria</i> genotypes on soil quality characteristics of an oxisol of the altillanura of the Meta Department of Colombia
Schulz Tatjana	Completed	University of Hohenheim, Germany	Evaluation of <i>Brachiaria brizantha</i> cv. Toledo and <i>Brachiaria</i> hybrids Mulato and Mulato II conserved as hay
Vivas Nelson	Completed	Universidad Nacional de Colombia, Palmira, Colombia	Evaluación agronómica de 144 accesiones de <i>Desmodium velutinum</i> como alternativa forrajera para las zonas de ladera del norte del departamento de Cauca

6.3 List of PhD students supervised

Name	Status	University	Title
Andersson Meike Stephanie	Completed	University of Hohenheim, Germany	Genetic diversity and core collection approaches in the multipurpose shrub legumes <i>Flemingia macrophylla</i> and <i>Cratylia argentea</i>
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 <i>Arachis pintoi</i>
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 <i>Brachiaria</i> 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, <i>Brachiaria</i> to low phosphorus soils
Reiber Christoph	On-going	University of Hohenheim, Germany	Encouraging adoption of research-based offerings with contrasting extension approaches

Name	Status	University	Title
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
Van der Hoek Rein	On-going	University of Hohenheim, Germany	Participatory research methods for forage- based technologies in Central-American hillsides.

6.4 List of Courses, Seminars, Training Events, and Field Days

Africa

Event	Dates	Location	Participants		
			M	F	Total
Participatory evaluation of improved forages with farmer groups		Tororo, Uganda			

Asia

Event	Dates	Location	Participants		
			M	F	Total
Use of forages for feeding rabbits	27 May 2005	P.R. China			60
Workshop to assess impact of LLSP/FSP on collaborator capacity in forage technology development with farmers	14 June 2005	P.R. China			10
Workshop to assess impact of LLSP/FSP on collaborator capacity in forage technology development with farmers	10 May 2005	Indonesia			12
Workshop to assess dissemination methodology	11-17 May 2005	Indonesia			12
Impact Assessment Planning Workshop	1-8 March 2005	Lao PDR			10
Training of farmers on adding value to forages	8 April 2005	Philippines			40
Workshop to assess impact of LLSP/FSP on collaborator capacity in forage technology development with farmers	15 April 2005	Philippines			9
Annual Review and Planning Meeting	24-28 Jan 2005	Vietnam			32

Asia

Event	Dates	Location	Participants		
			M	F	Total
Forage management and utilization; Basic goat nutrition	24-27 Jul 05	Lao PDR			12
Methodologies for forage technology dissemination	21-22 Sept 05	Cambodia			15
Impact Assessment Analysis Workshop	15-24 Nov 05	Lao PDR			9

LAC

Event	Dates	Location	Participants		
			M	F	Total
EMBRAPA scientists in methodologies to develop resistance to spittlebug in <i>Brachiaria</i>	18 Oct-7 Nov 2005	Cali, Colombia	2	1	3
Pasture establishment/Pasture seed quality/ IDR, INTA, UNA, MAG/FOR, Duwest	28-29 Oct. 2004	Nicaragua			55
Pasture establishment Pasture seed quality /DICTA, Duwest	9-11 Nov. 2004	Honduras			12
Pasture establishment Pasture seed quality/ICTA, U. de San Carlos, MAGA, FECAGUATE	18 March 2005	Guatemala			16
Pasture measurements CORFOGA, CGUS, Dos Pinos, Coopemontecillos, ECAG	1 July 2005	Costa Rica			15
Pasture conservation / INTA	22 Sept. 2005	Nicaragua			15
Small Farmers/ INTA/ IDR	23 Sept. 2005	Nicaragua			12
Small Farmers/MAGA	28 Sept. 2005	Guatemala			25
Training course on pasture seed harvesting and seed quality with emphasis on Toledo grass designed to Victoria small farmers associated in Prasefor (a pasture seed cooperative)	24 Apr- 5 May	Yoro, Honduras			28
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	5/21/2005	Sulaco, Yoro, Honduras	12	10	23

LAC

Event	Dates	Location	Participants		
			M	F	Total
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	6/7/2005	Yorito, Yoro, Honduras	20	4	24
Establishment and use of legumes for concentrate production	6/8/2005	Salitre, Yoro, Honduras	4	8	12
Characteristics and management (establishment) of Cowpea, <i>Lablab purpureus</i> and <i>B. brizantha</i> cv Toledo, hay and concentrate production and its use	6/8/2005	La Savanna, Yoro, Honduras	3	6	9
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	6/9/2005	Las Vegas/Victoria, Yoro, Honduras	13	1	14
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	6/14/2005	Alauca, El Paraiso, Honduras	13	1	14
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	6/15/2005	Jamastrán, El Paraiso, Honduras	15	3	18
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	6/16/2005	Jesus de Otoro, Intibuca, Honduras	6	1	7
Management and conservation (hay and silage) of forages, theoretical part with participative evaluations	6/17/2005	Catacamas, Olancho, Honduras	21	17	38
Forage conservation with practical training in little bag silage production	9/13/2005	Yoro, Yoro, Honduras	22	0	22
Silage making with special focus on little bag silage, practice	9/22/2005	Alauca, El Paraiso, Honduras	20	4	24
Silage making with special focus on little bag silage, practice	9/23/2005	Jamastrán, El Paraiso, Honduras	45	5	50
Silage making with special focus on little bag silage, practice	9/24/2005	Victoria, Yoro, Honduras	26	3	29
Forage conservation with practical training in hay and little bag silage, the characteristics of improved forages	9/27/2005	Las Tres Ceibas Olancho, Honduras	22	3	25

LAC

Event	Dates	Location	Participants		
			M	F	Total
Forage conservation with practical training in hay and little bag silage, the characteristics of improved forages	9/26/2005	Las Tres Ceibas Olancho, Honduras	19	8	27
Forage conservation with practical training in silage making (LBS and other silos), the characteristics of improved forages	11/29/2005	El Rodeo, El Paraiso, Honduras	7	2	9
Use of legumes for hay and concentrate preparation presented to 2 non-cattle farmer groups	12/9/2005	Yorito, Yoro, Honduras	2	10	12
Establecimiento de especies forrajeras multipropósito	20/04/2005	Bolivar, Valle, Colombia	12		20
Establecimiento de especies forrajeras multipropósito	18/05/2005	Versalles, Valle, Colombia	14	6	20
Comparación de métodos de conservación de forrajes con Vigna y Lablab (Henos y ensilajes en bolsas vs. formaleta), por métodos participativos con productores	20/12/2005	Quilichao, Cauca, Colombia	18	0	18
Gira Didáctica sobre manejo y utilización de especies forrajeras multipropósito con productores	13/04/2005	Quilichao, Cauca, Colombia	30	10	40
Gira Didáctica sobre siembra, manejo y utilización de especies forrajeras multipropósito con productores	27/07/2005	Zarzal, Valle, Cerrito, Risaralda y Chinchiná, Caldas, Colombia	40	10	50
Gira de evaluación de adaptación con productores de especies forrajeras multipropósito	12/09/2005	Bolívar y Sevilla, Valle, Colombia	10	3	15

7. List of Varieties and Tools released/Patents

7.1 Varieties: *Brachiaria* hybrid “Mulato II” released by Semillano in Colombia, July 2005

7.2 Tools: SoFT (Selection of Forages for the tropics) in a CD-R and in Internet, released at the International Grassland Congress in Ireland, June 26- July 1, 2005

7.3 Patent applied: Subbarao, G.V., Nakahara, K., Ishikawa, T., Ito, O., Rondon, M., Rao, I.M., and Lascano, C. 2005. Fatty acid in relation to NI activity

8. Adoption/Impact monitored

Seed of *Brachiaria* hybrid cv Mulato sold : Sales of Mulato seed in 2005 decreased relative to 2004 mainly as result of low availability of seed given the low yields (60-80 kg /ha) obtained. In a three year period we estimate that over 65,000 ha of pastures have been planted with Mulato in LAC.

Country	Seed Sold (kg)			Planted Area** (Ha)
	2003	2004	2005	
Argentina			500	125
Bolivia		600	1,000	400
Colombia	9,800	26,920	10,000	11,680
Costa Rica		2,250	1,265	878
El Salvador	1,400	2,000	500	975
Ecuador	2,500	5,900	500	2,225
Florida, USA	2,200	11,155	8,741	5,524
Guatemala	4,700	10,000	12,300	6,750
Honduras	8,000	7,500		3,875
Mexico	32,664	44,511	35,200*	28,094
Nicaragua	1,170	2,170	3,037	1,594
Panama	10,000	9,010	3,000	5,502
Venezuela			3,000	750
Total	72,994	122,016	79,043	68,372

* Mixture of Mulato and Mulato II;

** Estimated based on a sowing rate of 4 kg/ha

9. Awards to Staff in the Project

Outstanding Research Publication Award (ORPA): Cardona, César; Fory, Paola; Sotelo, Guillermo; Pabón, Alejandro; Díaz, Giovanna, and Miles, John. “Antibiosis and tolerance to five species of spittlebug (Homoptera: Cercopidae) in *Brachiaria spp*: Implications for breeding for resistance”. Apr. 2004. Economic Entomology 97 (2): 635-645.

Outstanding Support Staff Contribution Award (OSSCA): Guillermo Sotelo, Research Assistant, Tropical Forages Entomology

Francisco Luis Gallego Award: Sotelo Paola; Cardona César; Guillermo Sotelo, and Montoya James. “Resistencia de *Brachiaria spp* al salivazo: Efectos subletales de cultivares resistentes sobre los adultos de *Aeneolamia varia* (S. (Homptera:Cercopidae)”

10. List of IRS in the Forage Project

Lascano Carlos E, Project Leader and Animal Nutritionist; Headquarters
 Argel Pedro, Forage Agronomist: 0.35% CFC and 0.25% Papalotla, San José, Costa Rica
 Cardona Cesar, Entomologist (Host Plant –Resistance): 37.5% IP-5 and 37.5% IP-1; Headquarters
 Holmann Federico, Animal Production Systems/Economics: 50% CIAT and 50% ILRI; Headquarters
 Horne Peter, Forage Agronomist-Asia- 100% IP- 5 (until April, 2005)
 Kelemu Segenet, Pathologist: 50% in IP-5 and 50% PE-1; Headquarters
 Lentes Peter, Posdoc, Economics and GIS, 100%; Tegucigalpa, Honduras
 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% in IP-5, Managua, Nicaragua, (until July, 2005)
 Stur Werner, Forage Agronomist: 50% IP-5; Asia

11. Financial Resources

Headquarters

Source	Amount (US Dollars)*	Proportion (%)
Unrestricted Core	876,386	49
Restricted Core- Japan	40,000	2
Sub–Total	916,386	51
Special Projects	878,383	49
Total	1,794,769	100

Asia

Unrestricted core	0	
Restricted core	0	
Sub- Total	0	
Special Projects	897,153	100
Total	897,153	
Total Project	2,691,922	

Annex

List of Publications

Journal Articles in Refereed Journals (Published, In press and Submitted):

- Abello, J.F.; Kelemu, S. 2005. Hongos endofitos: Ventajas adaptativas que habitan al interior de las plantas. Revista Corpoica Ciencia y Tecnología Agropecuaria (In press).
- Andersson, M.; Jarvis, A.; Peters, M.; Schultze-Kraft, R. 2005. Is climate at collection site useful for the rapid assessment of diversity in germplasm collections? Comparative analysis of different approaches for germplasm characterization. Agriculture, Ecosystems and the Environment (submitted).
- Andersson, M.; Lascano, C.E.; Schultze-Kraft, R.; Peters, M. 2005. Forage quality and tannin concentration and composition of a collection of the tropical shrub legume *Flemingia macrophylla*. Science of Food and Agriculture (In press).
- Andersson, M.; Peters, M.; Schultze-Kraft, R.; Franco, L.H.; Lascano, C.E. 2005. Phenological, agronomic and forage quality diversity among germplasm accessions of the tropical legume shrub *Cratylia argentea*. Agricultural Science (In press).
- Andersson, M.; Peters, M.; Schultze-Kraft, R.; Gallego, G.; Duque, M.C. 2005. Molecular characterization of a collection of the tropical multipurpose shrub legume *Flemingia macrophylla*. Agroforestry Systems (submitted).
- Andersson, M.; Schultze-Kraft R.; Peters M.; Hincapié, B.; Lascano, C.E. 2005. Morphological, agronomic and forage quality diversity of the *Flemingia macrophylla* world collection. Field Crops Research (In press).
- Andersson, M.; Schultze-Kraft, R.; Peters, M.; Duque, M.C.; Gallego, G. 2005. Extent and structure of genetic diversity in a collection of the tropical multipurpose shrub legume *Cratylia argentea* (Desv.) O. Kuntze as revealed by RAPD markers. Plant Genetic Resources Characterization and Utilization (submitted).
- Ayarza, M.; Barrios, E.; Rao, I.M.; Amézquita, E.; Rondon, M. 2005. Advances in improving agricultural profitability and overcoming land degradation in savanna and hillside agroecosystems of tropical America. Nutrient Cycling in Agroecosystems (In review).
- Barahona, R.; Sanchez S.; Lascano, C.E.; Owen E.; Morris P.; Theodorou, M. 2005. Effect of condensed tannins from tropical legumes on the activity of fibrolytic enzymes from the rumen fungus *Neocallimastix hurleyensis*. Enzyme and Microbial Technology (Accepted)
- Barrios, E.; Cobo, J.G.; Rao, I.M.; Thomas, R.J.; Amézquita, E.; Jiménez, J.J. 2005. Fallow management for soil fertility recovery in tropical Andean agroecosystems in Colombia. Agriculture, Ecosystems and Environment 110:29-42.
- Begum, H.H.; Osaki, M.; Nanamori, M.; Watanabe, T.; Shinano, T.; Rao, I.M. 2006. Role of phosphoenolpyruvate carboxylase in the adaptation of a tropical forage grass, *Brachiaria* hybrid, to low phosphorus acid soils. Plant Nutrition. 29: 35-57.
- Fujisaka, S.; Holmann, F.; Peters, M.; Schmidt, A.; White, D.; Burgos, C.; Ordoñez, J.C.; Mena, M.; Posas, M.I.; Cruz, H.; Davis, C.; Hincapié, B. 2005. Forage Technologies to alleviate dry season feed Shortages: A diagnosis of Honduras and Nicaragua. Agricultural Systems (submitted).
- Gómez-Carabalí, A.; Rao, I.M.; Beck, R.F.; Ortiz, M. 2006. Rooting ability and nutrient uptake by tropical forage species that are adapted to degraded andisols of hillsides agroecosystem. Acta Facultatis Ecologie Vol. 12 (In press).
- Hausler, K.; Rao, I.M.; Schultze-Kraft, R.; Marschner, late. H. 2005. Shoot and root growth of two tropical grasses, *Brachiaria ruziziensis* and *B. dictyoneura* as influenced by aluminium toxicity and phosphorus deficiency in a sandy loam Oxisol of the eastern plains of Colombia. Trop Grasslands (In review).

- Holmann F, Rivas L, Argel P J and Pérez E 2004. Impact of the adoption of *Brachiaria* grasses: Central America and Mexico. *Livestock Research for Rural Development*. (16):98 (<http://www.cipav.org.co/lrrd/lrrd16/12/holm16098.htm>)*.
- Holmann, F.; Rivas, L.; Urbina, N.; Giraldo, L.; Guzmán, S.; Martínez, M.; Rivera, B.; Medina, A.; Ramírez, G. 2005. The role of livestock in poverty alleviation: An analysis of Colombia. *Livestock Research for Rural Development* (17):1:2005 (<http://www.cipav.org.co/lrrd/lrrd17/1/holm17011.htm>)
- Ishitani, M.; Rao, I.; Wenzl, P.; Beebe, S.; Tohme, J. 2004. Integration of genomics approach with traditional breeding towards improving abiotic stress adaptation: drought and aluminum toxicity as case studies. *Field Crops Research (Netherlands)* 90:35-45.*
- Kelemu, S.; Cardona, C.; Segura, G. 2004. Antimicrobial and insecticidal protein isolated from seeds of *Clitoria ternatea* (L.), a tropical forage legume. *Plant Physiology and Biochemistry* 42:867-873.*
- Kelemu, S.; Changshun, J.; Guixiu, H.; Segura, G. 2005. Genetic transformation of the tropical forage legume *Stylosanthes guianensis* with a rice chitinase gene confers resistance to *Rhizoctonia* foliar blight disease. *African Journal of Biotechnology* 4(10):1025-1033. <http://www.academicjournals.org/ajb/PDF/Pdf2005/Oct/Kelemu%20et%20al.pdf>
- Kelemu, S.; Mahuku, G.; Segura, G. 2005. An antifungal protein of the tropical forage legume *Clitoria ternatea* controls diseases under field and greenhouse conditions. *Phytopathology* 95:S52.
- Miles, J.W.; Cardona, C.; Sotelo, G. 2005. Recurrent selection in a synthetic brachiariagrass population improves resistance to three spittlebug species. *Crop Science* (accepted for publication November 1, 2005).
- Peters, M.; Hyman, G.; Jones, P. 2005. Identifying areas for field conservation of forages in Latin American disturbed environments. *Ecology and Society* 10(1):1. URL:<http://www.ecologyandsociety.org/vol10/iss1/art1/>
- Rivas, L.; Holmann, F. 2005. Potential Economic Impact in the adoption of new *Brachiarias* resistant to spittlebugs in the livestock systems of Colombia, Mexico and Central America. *Livestock Research for Rural Development* (17):5:2005. (<http://www.utafoundation.org/lrrd1705/holm17054.htm>).
- Schoonhoven, A.D.; Holmann, F.; Argel, P.; Perez, E.; Ordoñez, J.C.; Chaves, J. 2005. Estimation and comparison of benefits due to feeding hay and silage during the dry season on commercial dual-purpose cattle production systems in Honduras and Costa Rica. *Livestock Research for Rural Development* (submitted).
- Subbarao, G.; Ito, O.; Barry, W.; Sahrawat, K.L.; Rondon, M.; Rao, I.M.; Nakahara, K.; Ishikawa, T.; Suenaga, K. 2005. Scope and Strategies for Regulation of Nitrification in Agricultural Systems – Challenges and Opportunities. *Critical Reviews in Plant Sciences* (In review).
- Tscherning, K.; Barrios, E.; Lascano, C.E.; Peters, M.; Schultze-Kraft, R. 2005. Effects of sample post harvest treatment on aerobic decomposition and anaerobic *in-vitro* digestion of tropical legumes with contrasting quality. *Plant and Soil*, (269):159-170.
- Tscherning, K.; Lascano C.E.; Barrios, E.; Schultze-Kraft, R.; Peters, M. 2006. The effect of mixing prunings of two tropical shrub legumes (*Calliandra houstoniana* and *Indigofera zollingeriana*) with contrasting quality on N release in the soil and apparent N degradation in the rumen *Plant and Soil* 280 (1/2): 357-368.
- Wagatsuma, T.; Khan, M.S.H.; Rao, I.M.; Wenzl, P.; Yamamoto, T.; Kawamura, T.; Hosogoe, K.; Tawaraya, K.; Ishikawa, S. 2006. Methylene blue stainability of root-tip protoplasts can serve as an indicator of aluminum tolerance in a wide range of plant species, cultivars and lines. *Soil Science and Plant Nutrition* 51: 991-998.
- Watanabe, T.; Osaki, M.; Yano, H.; Rao, I.M. 2006. Internal mechanisms of plant adaptation to aluminum toxicity and phosphorus starvation in three tropical forages. *J. Plant Nutrition* (In press).

* These publications were not included in the 2004 Annual Report

- Wenzl, P.; Arango, A.; Chaves, A.L.; Buitrago, M.E.; Patiño, G.M.; Miles, J.W.; Rao, I.M. 2006. A greenhouse method to screen brachiariagrass genotypes for aluminum resistance and root vigor. *Crop Sci* 46:968-973.
- Wünscher, T.; Schultze-Kraft, R.; Peters, M.; Rivas, L. 2004. Early adoption of the tropical forage legume *Arachis pintoi* in Huetar Norte, Costa Rica. *Experimental Agriculture* 40(2): 257-268.*

Articles in Non-Refereed Journals and Working Documents:

- Beltrán, J.A.; Orozco, P.P.; Zapata, V.; Sanz, J.I.; Roa, M.C.; Schmidt, A. 2004. [Scaling out and scaling up: The importance of watershed management organizations](#). In: Pachico, D.; Fujisaka, S. (eds.). *Scaling up and out: Achieving widespread impact through agricultural research*. Centro Internacional de Agricultura Tropical (CIAT), Cali, CO. p. 153-171. (CIAT Publication no. 340; Economics and Impact series 3).*
- Cardona, C.; Sotelo, G. 2005. Mecanismos de resistencia a insectos: Naturaleza e importancia en la formulación de estrategias de mejoramiento para incorporar resistencia a salivazo en *Brachiaria*. *Pasturas Tropicales* 27 (2):2-11.
- Fujisaka, S.; Holmann, F.; Peters, M.; Schmidt, A.; White, D.; Burgos, C.; Ordoñez, J.C.; Mena, M.; Posas, M.I.; Cruz, H.; Davis, H.; Hincapié, B. 2005. Estrategias para minimizar la escasez de forrajes en zonas con sequías prolongadas en Honduras y Nicaragua. *Pasturas Tropicales*. 27(2):73-92.
- Hare, M.D. and P.M. Horne (2004). Forage seeds for promoting animal production in Asia. Paper presented at the Asian Seed Congress in Seoul, Korea (13-17 September 2004). Published as Asia and Pacific Seed Association (APSA) Technical Report No. 41 (APSA, Bangkok).*
- Holmann, F.; Rivas, L. 2005. Los forrajes mejorados como promotores del crecimiento económico y la sostenibilidad: El caso de los pequeños ganaderos de Centroamérica. Centro Internacional de Agricultura Tropical (CIAT). Cali, CO. 70 p. (Documento de trabajo No. 202)
- Rivas, L.; Holmann, F.; García, J. 2005. Nuevos sistemas diversificados de producción agropecuaria incluyendo componentes y servicios ambientales: Una evaluación económica en la altillanura colombiana. Centro Internacional de Agricultura Tropical (CIAT). Cali, CO. (Documento de trabajo No. 204)
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Monographs, Books and Book Chapters

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