Tropical Grasses and Legumes:

Optimizing Genetic Diversity for Multipurpose Use

Courtesy of Chaisang Phaikaew

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Tropical Grasses and Legumes: Optimizing Genetic Diversity for Multipurpose Use (Project IP5)

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Cover photo: Commercial seed harvest of hybrid *Brachiaria* cv. Mulato in Thailand. This initiative of Semillas Papalotla will benefit approximately 1,800 Thai farmers, each with an average of less than 1 hectare of Mulato. Photo courtesy of Chaisang Phaikaew.

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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 WORK BREAKDOWN STRUCTURE 2004

PROJECT PURPOSE

To identify and deliver to farmers superior gene pools of grasses and legumes for sustainable agriculture systems in subhumid and humid tropics

OUTPUTS	**Grass and legume genotypes with high forage quality attributes are developed**	**Grass and legume genotypes with known reaction to pests and diseases, and to interaction with symbiont organisms are developed**	**Grass and legume genotypes with superior adaptation to edaphic and climatic constraints are developed**	**Superior and diverse grasses and legumes delivered to NARS partners are evaluated and released**
ACTIVITIES	⊄# Screening of *Brachiaria* hybrids for high digestibility and protein ⊄# Animal production potential with selected grasses and legumes ⊄# Assessment of the potential of tanniferous legumes to improve ruminant nutrition	⊄# *Brachiaria* genotypes resistant to biotic and abiotic stresses ⊄# Screening *Brachiaria* genotypes for spittlebug resistance ⊄# Identify host mechanisms for spittlebug resistance in *Brachiaria* ⊄# Selection of *Brachiaria* hybrids for resistance to *Rhizoctonia* foliar blight disease ⊄# Elucidate the role of endophytes in tropical grasses ⊄# Association of bacteria with *Brachiaria* genotypes ⊄# Antifungal proteins in tropical forages	⊄# Genotypes of Brachiaria and *Arachis* with adaptation to edaphic factors ⊄# Genotypes of *Brachiaria* with dry season tolerance ⊄# Grasses with adaptation to poorly drained soils ⊄# Nitrification inhibition in tropical grasses ⊄# Legumes (herbaceous and woody) with adaptation to acid soils and drought ⊄# Annual legumes for multipurpose use in different agroecosystems and production systems	⊄# Partnerships in LAC to undertake evaluation and diffusion of new forage alternatives ⊄# Partnerships in Asia to undertake evaluation and diffusion of new forages alternatives ⊄# Partnerships in Africa to undertake evaluation and diffusion of new forage alternatives ⊄# Forage Seeds: Multiplication and deleivery of experimental and basic forage seeds ⊄# Enhancing livestock productivity in Central America ⊄# Impact of forage research in LAC ⊄# Expert systems for targeting forages and extension materials for promoting adoption of forages ⊄# Facilitate communication through journals, workshops, and the Internet

6.0 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 to 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	∉# 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

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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

7.0 Research Highlights

Improvement of *Brachiaria* for biotic and abiotic stresses

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

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

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.

8.0 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 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".