Tropical Forages: A Multipurpose Genetic Resource

The Importance of Tropical Forages

Much of the feed for livestock in developing countries comes from various tropical forage species. In Latin America as much as 70 percent of the total agricultural land area is in native and planted pastures. Worldwide, livestock use 3.4 billion hectares of grazing land as well as the production from about a quarter of the land in crops. This amounts to more than two-thirds of total agricultural land area and a third of total land area. Forage species are thus a prominent feature of agricultural landscapes around the world.

In the humid and subhumid tropics, most pastures are in native species of inferior nutritional quality. As a result, livestock productivity in native pastures tends to be quite low, and the possibilities for sustainable intensification are limited. In recent decades, though, forage specialists have identified a wide variety of tropical forage grasses and legumes that are highly productive, show superior nutritional quality, and are well suited to marginal agroecosystems characterized by low soil fertility and drought. In Latin America much progress has been made toward commercializing and promoting these improved forages, notably the grass *Brachiaria decumbens,* which is of African origin. Despite heavy pest pressures and other limitations, introduced grasses have had a significant impact on livestock productivity across the region. Efforts to introduce improved forages are also under way in Africa and Asia but are less advanced.

The need for improved forages in all regions of the developing world can only increase with continued massive growth in global demand for livestock products. According to many economists, a "livestock revolution" is under way, which will continue well into the next century. From 1983 to 1993, meat consumption in the developing world leaped from 14 to 21 kilograms per capita, while milk consumption rose from 35 to 40 kilograms. The increases were particularly notable in Asia. Consumption of livestock products also grew in Latin America, while declining in sub-Saharan Africa.

Increased demand is driven largely by population growth, rapid urbanization, rising incomes, and diversification of human diets. Given current trends, demand for meat in the developing world is expected to grow from the current 206 million tons to 275-310 million tons or more by the year 2020.

This is good news for rural people in the developing world. Increased demand for livestock products could provide small farmers with new opportunities to increase incomes through more intensive production. Hundreds of millions of them already depend heavily on livestock for income. Often, animals are their only means of accumulating and saving capital and of obtaining insurance against crop or other losses.

As the incomes of the poor in both rural and urban areas rise, they will be able to improve their diets by consuming more livestock products. Meat and milk provide protein, calcium, vitamins, and other nutrients that are lacking in many of the staple crops on which poor consumers mainly depend.

What remains to be seen is whether economic conditions and agricultural policies will be conducive for small farmers to intensify production in response to growing demand. Often, these farmers will be competing with highly efficient industrial production systems located near urban markets. In order for small farmers to thrive in this environment, they will need to move away from the traditional patterns of low-input, extensive livestock production.

Another concern is that greatly increased livestock production will incur unacceptably high environmental costs. Though some livestock production systems actually result in better management of natural resources, others have led to widespread degradation of pasture land, involving serious soil erosion, or to deforestation, resulting in biodiversity loss.

Appropriate combinations of superior forage grasses and legumes could provide some of the answers to these and other concerns. Much recent experience in Latin America and Asia has demonstrated that new forage-based technologies are highly effective for intensifying meat and milk production on small farms. They also show potential as partial substitutes for concentrate supplements in feeds, particularly during the dry season, thus lowering production costs.

In addition, many forage species contribute to more sustainable land management by helping regenerate degraded soils and replenish the nitrogen supply of the production system. Forage plants also help reduce erosion and control weeds. Moreover, since many of the new forages are well adapted to poor soils, they can intensify livestock production even under marginal conditions, thus freeing more favorable environments for cereals and other crops. Some recent experience in a hillside environment of Central America further suggests that improved forages, by permitting more intensive livestock production on areas already in pastures, can remove some of the pressure on adjacent forest land.

That is why CIAT scientists refer to tropical forages as a "multipurpose genetic resource." These plants have tremendous potential and appeal as a way of improving the lot of small farmers as well as poor consumers, while having benign effects on natural resources.

Research for Development

Challenge

Nearly three decades of tropical forage research at CIAT have confirmed the effectiveness of various grass-legume combinations both for improving livestock nutrition and recuperating degraded land. Focusing initially on the vast tropical savannas of South America, this research has gradually expanded in scope to include the forest margin and hillside agroecosystems of tropical America.

The savannas are characterized by extensive cow-calf operations with low management input and little use of purchased fertilizers or seeds, with corresponding low productivity. The savanna area planted to improved grass pasture has expanded, but the proportion of degraded pastures has also increased alarmingly.

At the forest margins, land is used initially for subsistence agriculture after the felling and burning of native forest. The decline of soil fertility and growth of weeds on cleared land leaves farmers with little choice but to clear more land. Many of these smallholders eventually convert cleared land to the production of dual-purpose cattle in grass pastures, characterized by low productivity and rapid degradation.

Livestock production in hillside areas is limited by steep and irregular slopes subject to soil erosion. Often, when farmers have not raised enough forage during the growing season to feed their cattle during the dry season, they allow them to graze in forested areas. The overgrazing that may result from this practice exposes the soil to further degradation, while animal weight gain and milk production are severely curtailed.

Though dealing mainly with these three agroecosystems in tropical America, CIAT forage scientists also provide new germplasm for the uplands of Southeast Asia through the Center’s work on cropping systems in that region and for sub-Saharan Africa in cooperation with the International Livestock Research Institute (ILRI).

With such a diversity of target environments, it obviously takes more than one or a few forage species to meet the needs and fit the conditions of many individual production niches. Thus, the central challenge of forages research is to provide an extensive portfolio of germplasm options for multiple uses in smallholder production systems.

To accomplish this requires a substantial effort in germplasm evaluation, aimed at generating information on key traits of the most promising grass and legume species, including their quality attributes, resistance to pests and diseases, and adaptation to soil and climatic conditions. In selected cases we must also undertake forage breeding to supply combinations of traits that do not exist in the natural germplasm currently available.

As described in the sections that follow, CIAT forage scientists and their national partners have come far indeed toward the goal of making a rich array of forage diversity available for improving livestock production and land management.

Genetic resources

Grass-legume mixtures are subtle combinations, which must be created to fit the conditions of specific environments. One legume, for example, may promote better nutrition for calves, while another is useful in places with extended dry seasons, and another is drought tolerant and adapted to acid soils.

In searching for suitable species, CIAT researchers and their partners draw on an extensive collection of over 22,000 forages (including some 18,400 samples of 654 different legume species and about 1,900 samples of 178 grasses). This germplasm is held in trust at Center headquarters for the Food and Agriculture Organization (FAO) of the United Nations. Safeguarding, studying, and sharing the germplasm are fundamental responsibilities implied by CIAT's global mandate for tropical forages research within the Consultative Group on International Agricultural Research (CGIAR). To facilitate the evaluation and targeting of forage grasses and legumes, Center scientists have developed core collections of key species. These are small but representative samples of the complete germplasm holdings.

Nutritional quality of forages

Recent research at CIAT on the quality attributes of forages has focused on the role of antinutritional factors, particularly condensed tannins (CTs). These substances occur at high levels in many herbaceous and woody legumes and are known to reduce the intake, digestion, and utilization of these forage species by ruminant animals.

The aim of our research on CTs is to gain a better understanding of how they affect ruminant nutrition, so we can develop more efficient procedures to screen legumes for nutritional value and design better strategies for incorporating these species into livestock feeding systems. Improved screening methods have been developed and are now being used to characterize a wide range of legumes. Based on the results, we are compiling a list of legume species indicating their quality attributes as feed sources.

Another vital part of this work involves measuring the impact of selected legumes on livestock performance at the farm level, based on factors (such as live-weight gain and milk production) that are closely associated with the quality attributes of legumes. Obviously, farmers will not adopt legumes just to regenerate degraded soil but to achieve significant improvement in their livestock production.

Recent results confirm that legumes can have a sizable impact on meat and milk production, when used in different feeding systems on dual-purpose cattle farms. On-farm trials have consistently demonstrated that, for example, the herbaceous legume *Arachis pintoi*, combined with grasses, can increase the milk yield of cows by 10 to 15 percent, compared with feeding cows on pastures consisting of introduced grasses alone.

***Genetic improvement of* Brachiaria**

The forage germplasm now available satisfies many of farmers' requirements but by no means all. Some important traits are lacking, as is the case with resistance to the ubiquitous grassland spittlebug in *Brachiaria* spp. CIAT researchers have embarked on breeding of this trait for two compelling reasons. First, *Brachiaria* grasses are the most widely grown forage species in tropical America, occupying more than 70 million hectares. And second, the spittlebug dramatically reduces forage productivity and persistence, contributing to extensive pasture degradation in the region.

Brazilian researchers have released a spittlebug resistant cultivar of *B. brizantha* cv. Marandú, but this species lacks tolerance to infertile acid soils, which are common in tropical savannas. CIAT researchers have found that *B. decumbens*, in contrast, is well adapted to such soils, largely because of its high level of aluminum resistance. This species also increases beef production dramatically, boosting weight gain per hectare per year by a factor of 10, compared with native grasses. The challenge is to combine the spittlebug resistance of *B. brizantha* with the desirable traits of *B. decumbens* in a wide range of cultivars that give farmers multiple options for crop-livestock systems in different environments.

One complication in breeding *Brachiaria* is that the grass normally reproduces through apomixis, a process involving the production of asexual seed. Two decades ago, Belgian scientists provided a way around apomixis by creating a polyploid sexual *Brachiaria* plant that serves as a bridge for combining attributes from distinct, naturally asexual parents.

Rapid and reliable screening methods have been developed to evaluate *Brachiaria* hybrids for resistance to spittlebug and aluminum toxicity. Through field evaluation of a *Brachiaria* population consisting of sexual genotypes, 11 were selected for resistance under artificial infestation and were recombined to form a new cycle of the population in 1998. Crossing of elite apomictic genotypes to this population is now generating large numbers of superior, spittlebug-resistant, aluminum-resistant clones, which will be evaluated for commercial release.

The use of molecular markers for apomixis, spittlebug and aluminum resistance, and other traits shows promise for further improving the efficiency of selection. For this purpose CIAT scientists are now generating a large, segregating *Brachiaria* population to identify molecular markers that are associated with key traits.

Anthracnose resistance

Another major constraint being addressed by forage researchers at CIAT is the anthracnose fungus (*Colletotrichum gloeosporioides*), which is a serious obstacle to wider use of *Stylosanthes* spp. This is a legume of South American origin that shows much potential for improving livestock production and land management in the tropics and subtropics. Anthracnose is also becoming a problem on another important forage legume, *Arachis pintoi*.

Center scientists are screening *Stylosanthe*s germplasm for anthracnose resistance, while examining pathogen diversity and the geographic distribution of its various races, work that is vital for developing effective programs for breeding anthracnose resistance.

Endophytes for plant protection

A novel approach to plant protection in tropical forages centers on endophytes, microscopic fungi that grow between the cells of plant tissues. Commonly used in forage and turfgrasses of the temperate zone, endophytes help the host plant by making it drought tolerant and resistant to insect pests. However, in some species the toxicity that repels pests also sickens cattle that graze on the grass. The challenge for research is to identify the endophyte strains that are safe for use in pasture grasses. Once improved grasses such as *Brachiaria* are artificially infected with these safe strains, the association will be permanent, since the endophytes are passed on through the seeds.

Though considerable research has been conducted on endophytes in grasses of the temperate zone, little is known about these fungi in tropical grasses. One of the first tasks of research on endophytes was to develop protocols for detecting the fungi. Such methods are now available and have been used to identify, for the first time, endophytes in *Brachiaria* similar to those reported in temperate grasses. Molecular analysis has revealed genetic differences among the endophytes isolated in *Brachiaria*. Surveys are now under way to detect endophytes in both *Brachiaria* spp. and native grasses to determine the distribution of these fungi in tropical America.

Another key step has been to identify methods for artificially inoculating *Brachiaria* with endophytes. In addition, our scientists are examining the effects of these fungi on other fungi that cause diseases in tropical grasses. The results so far show that endophytes can provide effective control. To further explore their potential benefits, researchers are testing *Brachiaria* clones containing endophytes for tolerance to other pathogens as well as insect pests and drought.

Adaptation of forages to soil and climate

Forage evaluation at CIAT would be decidedly incomplete without a major effort to determine and document the tolerance of key species to the main abiotic stresses of grasses and legumes in savannas, forest margins, and hillsides.

One major limitation of forage production across environments is the limited supply of nutrients, especially phosphorus, in acid soils. Many tropical forages are well adapted to these soils and thus offer one of the best options for managing them. Collaborative research at CIAT has shown that the ability of some forages to tolerate low soil fertility is associated with certain root and shoot attributes. Both grasses and legumes adapt to low nutrient supply by partitioning increased dry matter to the roots at the expense of leaf and shoot growth. There appears to be significant genetic variation for this ability in *Brachiaria* spp. and *Arachis pintoi*. The vigorous root systems of tropical forages also enable them to sequester huge quantities of carbon dioxide, which otherwise would be recycled to the atmosphere, heightening the threat of global warming.

A major constraint of small-scale livestock production in hillsides and forest margins is shortage of forage during the dry season, which leads to overgrazing. If smallholders are to intensify production in these environments, it is vital that they have new forage species with tolerance to a long dry season. Toward this end CIAT researchers are conducting extensive evaluations of promising species, particularly the shrub legumes *Cratylia argentea* and *Calliandra calothyrsus*.

Partnerships

Forage researchers at CIAT rely heavily on partners in national agricultural research systems, the private sector, and advanced research institutes.

National programs

Throughout the 1980s testing of promising grass and legume species in Latin America took place through the International Network for the Evaluation of Tropical Pastures

(RIEPT), which involved 95 institutions in 22 countries. The RIEPT marked a decisive break with historic neglect of tropical forages in the region's agricultural research. The network was highly successful in building national research capacity and in establishing close ties among national programs and between them and CIAT. A similar network was formed for evaluating pastures in West Africa.

Although these networks are no longer active, intensive forage evaluation and related research continue today under other types of cooperative arrangements. In this work CIAT naturally maintains especially close ties with the Colombian Corporation for Agricultural Research (CORPOICA) and with various universities in its host country. Given the vast areas planted to pastures in Brazil, CIAT also works closely with centers of the Brazilian Agricultural Research Enterprize (Embrapa), particularly in germplasm collection and evaluation and in genetic improvement of *Brachiaria*. For the benefit of these and many other national programs, Center scientists offer training and organize regional workshops on key forage species, research methodologies, and related themes.

Networks for participatory evaluation of forages

The RIEPT model for cooperative research has been succeeded by a new kind of network centering on farmer evaluation of forages. Under this new model, national partners in selected countries of a region develop and evaluate forage technologies with farmers for specific livestock systems.

The Tropileche project, for example has focused on dual-purpose livestock production in Central America and the Andean zone. Throughout the humid and subhumid regions of tropical America, dual purpose ruminants—cattle, sheep, and goats raised for both meat and milk—account for most animal production on small farms. Dual-purpose cattle make up 78 percent of the region's total herd and produce 41 percent of its milk. Under CIAT coordination Tropileche worked to provide smallholders with new options for intensifying livestock production, while improving natural resource management. Part of a wider international research effort—the CGIAR's Systemwide Livestock Program, which is coordinated by ILRI—the project has involved researchers, extensionists, and farmers in Costa Rica, Honduras, Nicaragua, and Peru.

Another example of this networking approach is the Forages for Smallholders Project (FSP), which was jointly coordinated by CIAT and the Commonwealth Scientific and Industrial Research Organisation (CSIRO) of Australia. The national partners involved in the project have used participatory research approaches with farmers in Indonesia, Laos, Philippines, Thailand, and Vietnam. Together, they have designed, developed, and tested forage systems with broadly adapted grasses and legumes identified by the project.

To provide stronger support for such projects, CIAT scientists have formed an interdisciplinary team that will develop improved methods for targeting forage germplasm in hillside environments, drawing on participatory approaches and geographic information systems (GIS).

Private sector

CIAT is building strong ties with the private sector in forage research and development. For example, in Colombia's Caquetá Department, we collaborated with Nestlé in a project designed to recuperate degraded pastures, using forage legumes, in the forest margins. We are also collaborating with a Mexican seed company, Paplotla, in developing and diffusing *Brachiaria* hybrids. In upstream research on endophytes, we are working with the US company BioWorld on methods for detecting these fungi in tropical grasses.

Advanced research institutes

Center collaboration with advanced research institutes in the developed world is especially vital for resolving the methodological challenges in forages research. In work on antinutritional factors in legumes, for example, we work closely with colleagues at the Institute of Grassland and Environmental Research (IGER) and Oxford Forestry Institute (OFI) in the UK. Endophytes research at CIAT depends on strong relationships with Japan's National Grasslands Research Institute and with the University of Rutgers in the USA. Finally, our efforts to identify forage attributes that are associated with adaptation to acid soils has benefited greatly from cooperation with the Universities of Hohenheim (Germany) and Vienna (Austria) as well as Japan's Hokkaido University.

Impact

Since 1970 national programs in 14 countries have released 45 tropical forage cultivars that were derived from germplasm selections provided by CIAT. Most of these cultivars are grasses, which have been widely adopted in Latin America for pasture improvement.

When expressed as a percentage of the total pasture area in specific countries, the adoption rates seem low; the highest, for Costa Rica, is just 10 percent. But the figures for area planted to these varieties are impressive. In Brazil, for example, where the area in pastures is vast (180 million hectares), the percentage of that area sown to CIAT-related cultivars amounts to more than 5 million hectares.

The total area planted to CIAT-related cultivars in Latin America is estimated at about 6.8 million hectares. And the cumulative value of the meat and milk production increases made possible by these improved cultivars is estimated at $1.4 billion in 1990 US dollars. The internal rate of return to the Center's forage research is a respectable 36 percent, indicating that the work has been quite effective.

Even so, given the low percentage of total pasture area planted to improved varieties, there is obviously a lot of scope for further impact. It is estimated that 90 percent of the grazing land in tropical America is still in native pastures. The pace at which new forage technology continues to spread, however, will depend on broad trends in the livestock sector, which are heavily influenced by government policies.

In Latin America increased livestock production has been brought about during recent decades mainly by expanding the area used for cattle, particularly in tropical savannas, forest margins, and hillsides. Farmers have had little incentive to adopt technology that increases production per unit of land. Nonetheless, the proven ability of improved grasses to boost livestock productivity by a factor of 16 over native grasses is a considerable enticement. And adoption of these grasses will no doubt increase as demand for livestock products continues to grow. This will happen a lot faster, though, if government policies are designed to encourage intensification rather than area expansion of domestic livestock production.

Adoption of forage legumes has been fairly limited so far, again because farmers lack incentives to intensify production, but also because many do not recognize the long-term benefits that forage legumes bring by enhancing the soil and making production more sustainable. Nonetheless, recent experience has revealed many opportunities in tropical Asia and America for integrating forage legumes into different production systems.

In southern China, for example, a CIAT selection of the tropical American legume *Stylosanthes guianensis* is currently sown on about 50,000 hectares as a cover crop for rubber and fruit trees. It reduces the need for chemical fertilizers, helps conserve moisture, and controls both erosion and weeds. In addition, farmers harvest the *Stylosanthes* leaves and use them as an ingredient in highly nutritious animal feeds. Other forage species, including *Centrosema acutifolium*, *C. macrocarpum*, and *Arachis pintoi*, are also being used as cover crops in banana, coffee, palm, pepper, citrus, and other commodities in several Latin American countries.

Since 1996 the above-mentioned Tropileche project has demonstrated the potential for intensifying small dual-purpose livestock production (i.e., for meat and milk) through the introduction of various grass-legume combinations. At the same time, the Forages for Smallholders Project in Southeast Asia has led to the adoption of improved germplasm in a wide variety of upland production systems. Perhaps most important, these projects have enabled us to devise farmer participatory research methods, which have proved highly effective in creating appropriate forage technologies for diverse production niches.