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TROPICAL PASTURE RESEARCH IN ACID, INFERTILE SOILS OF LATIN AMERICA: PRESENT STATUS AND NEEDS FOR THE FUTURE

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One of the main conclusions of the seminar on the "Potential to Increase Beef Production in Tropical America" held at CIAT five years ago was the need to increase efforts in tropical pasture research in order to bring it in line with efforts on animal management and health (2). An in-depth review of pastures and forages research in the region, published by Crowder (1) in 1974 showed that there were significant, but largely scattered pasture research efforts throughout tropical Latin America, few of which had any real linkages to soil constraints or to animal productivity. The purpose of this Seminar is to review the present state of knowledge, five years after those two reviews. This chapter attempts to summarize what is known and what is still unknown, drawing from the papers presented, the question and answer periods, and the general discussion sessions. The author is grateful to the chairmen of the general and discussion sessions**, for providing valuable summaries, on which many of the following comments are based.

PRESENT STATE OF KNOWLEDGE

Conceptual

Three major conceptual themes emerged from the Seminar. First, in order to increase beef production an integrated attack on the constraints affecting the soil-pasture-animal continuum is needed. To accomplish this an interdisciplinary team is required both to develop improved beef production technology and transfer it to the users. Second, the Seminar participants agreed that the main constraint preventing increased beef production is animal nutrition caused by insufficient pasture both in terms of quantity and quality. Many scientists involved in major research efforts which have concentrated on improved animal breeding or health have gradually realized that notwithstanding the importance of adequate management and health of tropical beef cattle, poor pasture production is by far the most limiting factor in marginal soil areas. The third major theme is the growing ecosystem focus on acid infertile soils, which cover about 51% of tropical America. A number of national and international institutions are giving top priority to savanna and jungle Oxisol-Ultisol regions as the areas with the greatest potential to increase beef production in our continent, where unlike tropical Asia and Africa, beef is a major component of the diets of poor urban and rural Latin Americans. The Oxisol-Ultisol regions are rapidly developing and almost invariably, land settlement starts with extensive, pasture-based beef production. If productive and persistent pasture technologies are developed to withstand the acid soil infertility and

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climatic stress, many of the better soils located close to markets, presently used to produce beef, can be used more efficiently for intensive food crop production.

The ecosystem

Many of the Seminar authors have carefully described the climate, soil and native vegetation of the areas in which they work, revealing their awareness of ecosystem differences, which may limit the extrapolation of results to other regions. In broad terms, Alvim describes the potential of the Amazon region for pasture-based beef production and makes use of actual experience to put into perspective the excessive pessimism of those who fear that the opening up of the tropics will result in "catastrophic" ecological disasters. The report of Serrão and coworkers from Eastern Amazonia that pastures significantly reduce the rate of soil fertility decline after clearing and burning tropical forest has major ecological implications. Toledo and Morales further show that beef production in the Amazon can reach very high levels.

Cochrane's paper presents a systematic way to synthesize available information on climate, soil, landscape and vegetation into land systems, units small enough to allow quantification of variability and implications for livestock production. Similar considerations are also needed for identifying ecosystems with high potential for tropical pasture seed production, which as Hopkinson and Reid indicate, are usually not the same areas where pastures are to be grazed.

The quest for adapted forage germplasm

The unifying theme of the Seminar is the continuing need for improved ecotypes of both grass and legume pasture species, which are better adapted to Oxisol-Ultisol regions of tropical America, and to subtropical regions of North America and Australia.

While there are few well adapted, productive grass species, only two of them cover much of the improved pastures area in the acid soils of tropical America: *Brachiaria decumbens* in the more stressful soils, and *Panicum maximum* in the somewhat better soils. *B. decumbens* is threatened in some areas by spittlebug attacks, particularly in the more humid regions, while *P. maximum* disappears with time when its nutritional needs are not adequately met. Other major species such as *Hyparrhenia rufa* are productive only in areas with better soils or at higher levels of fertilizer and lime applications, which are probably uneconomical in much of the Oxisol-Ultisol regions.

The need for expanding the germplasm base of tropical pasture grass species is obvious, but it is greatly overshadowed by the lack of appropriate pasture legumes. All grasses need nitrogen, which in this energy short world, should be fixed from the air at low cost by legume-*Rhizobium* symbiosis. No lasting impact can be expected until persistent and productive grass-legume pastures are developed for the Oxisol-Ultisol regions of Latin America. Hutton's paper reports almost no successes in persistent grass-legume pastures in acid, infertile soils of this continent to date. Very encouraging results with grass-legume pastures are reported during the first year or two, but the legumes tend to disappear afterwards, due to a variety of reasons such as poor adaptation to acid soils, tolerance to insect and disease attacks, inadequate mineral nutrition, and overgrazing.

Paradoxically, Latin America is the richest source of tropical forage legume germplasm in the world. Australian Scientists collected many ecotypes decades ago, selected them for adaptation to their conditions and developed the only large-scale, legume-based beef production in the tropical world. The papers by Hutton, Teitzel, Evans, and Roberts describe and update this achievement.

Until recently, pasture legume work in Latin America has consisted largely of repatriation of the Australian cultivars back to their center of origin. Sánchez and Isbell point out the fundamental differences in climate and soils between the tropical pasture regions of Australia and Latin America, which largely limit the transferability of results from one continent to the other. Since in tropical Australia the soils are generally not acid and the climate is characterized by long and cool dry seasons, much of the adapted germplasm has failed when introduced into acid soil regions of Latin America. Also they are subjected to devastating disease and insect attacks, which are unimportant in Australia. The successful transfer of Australian cultivars is limited to high latitude, high soil pH regions with cool, long dry seasons, but not to low latitude, hot, humid tropical America.

Fortunately, new and coordinated efforts are underway for collecting, cataloging and evaluating the forage germplasm resources of Latin America, as Schultze-Kraft and Giacometti describe. Hecht's report emphasizes the potential value of browse species, which traditionally have been of more interest to botanists than cattle producers. It is clear that tropical pasture scientists in Latin America are beginning to master their continents' forage germplasm resources.

Technology components

The processes of testing new germplasm for adaptation, productivity and persistence in acid soil regions involves a series of technology components, some of which rely heavily on purchased inputs and some of which require only minimum inputs. Both approaches are well illustrated in many papers of this Seminar, and such differences are expected in a region with countries having widely different economic, social and political conditions. In spite of these differences, the Seminar papers indicate a rapid transition from classic, temperate region research emphasizing the elimination of stresses by heavy fertilization, liming, irrigation, pest control, hay making, silage, and concentrate supplementation, to attempts to overcome, and in some cases, take advantage of acid soil infertility.

Several papers describe components of low input technology aimed at adapting the forage species to acid soil stresses. Spain's paper shows the abundance of grass and legume pasture species which tolerate high levels of aluminum saturation in the soil, in sharp contrast to most crop species and many commercial tropical forage species such as *Chloris gayana, Hyparrhenia rufa* and *Glycine wightii.* The use of aluminum tolerant species such as *Brachiaria decumbens, Stylosanthes guianensis* and many others, effectively eliminates the need of liming, although in soils with extreme calcium deficiency, this nutrient has to be supplied.

The paramount limiting nutrient, however, is phosphorus which is not only costly to apply but is subject to chemical fixation in clayey Oxisols and Ultisols. The review by Fenster and León shows that very important differences exist among and within forage species in their ability to grow well at low levels of available soil phosphorus. Also their paper indicates that if the soils are kept acid and aluminum tolerant pasture species are grown, low reactivity rock phosphates are as efficient as superphosphate in supplying phosphorus to the pasture, but as a fraction of the cost. By keeping the soil acid, the high energy requirement of superphosphate manufacturing plants can be replaced by the chemistry of acid soils. Tropical America is blessed with vast rock phosphate deposits of low reactivity. Their use in the Oxisol-Ultisol regions could make a major contribution towards overcoming this major limiting factor in pasture nutrition.

After phosphorus deficiency is overcome, nitrogen is commonly the next most serious limiting factor. Pure grass pastures run out of nitrogen with time and as Hubbell points out, the possibility of associative symbiosis between free living N-fixing bacteria such as *Spirillum lipoferum* and tropical grasses is of no practical significance. The use of nitrogen fertilizers on grass pastures is severely limited by their high cost to very special circumstances as Teitzel, Evans, Kretschmer and Snyder, and Toledo and Morales point out. The best alternative is nitrogen fixation by legume-*Rhizobium* symbiosis. Halliday's results show significant advances in obtaining effective symbiosis in acid-tolerant tropical pasture legumes, by the systematic selection of strains and pelleting practices. The concept that most tropical pasture legumes nodulate freely in acid soils is now discarded.

Other essential nutrients are limiting in acid soil regions; their identification and correction is essential to guarantee persistent grass-legume associations. Very little is known about the nutrient status of Oxisol and Ultisol regions of Latin America in relation to the requirements of both grass and legume pasture species. Teitzel describes the Australian approach to identify such limitation based on geology, native vegetation and missing element trials, and several papers from Latin America follow this approach to a limited extent. Most Latin American countries, however, have well equipped soil testing laboratories which could develop site-specific recommendations if the nutritional requirements of the pastures were known. Of major importance to our region are potassium, sulfur and magnesium deficiencies, and among the micronutrients zinc, boron, copper and molybdenum seem to be the most widely limiting ones.

One of the major themes of the Seminar was that the nutritional requirements of grass and legume species must be met in order to have persistent pastures. These requirements must be identified and corrected in the most economical way, particularly if the species are tolerant to aluminum toxicity and to low levels of available soil phosphorus.

Conventional pasture establishment techniques have been developed for savanna and jungle regions but they are generally costly. The paper by Nores and Estrada, and economic data presented in others suggest very strongly that improved pasture establishment costs should be reduced to the greatest possible extent in order to make these practices more profitable. Some promising alternatives have been identified such as low density plantings, described in Spain's paper, and methods for gradually improving the native savanna. Another is the use of crops as precursors of pasture establishment, a practice already in use in Brazil, Peru and other countries and described in papers by Kornelius *et al.* and Toledo and Morales. Burning the native savanna or the tropical rain forest is an integral component of most pasture establishment methods, and in both cases, an ecologically sound one.

The availability of sexual seed of the improved pasture species is another essential technology component for increasing beef production. Ferguson provides a practical classification of the main pasture seed production systems in tropical America and summarizes the present status. Rayman describes his very interesting experiences as a commercial seed producer in Brazil. Much can be learned from the grass seed production experiences in Africa described by Boonman, and of legumes in Australia described by Hopkinson and Reid. Low latitudes is a major constraint in forage seed production particularly in countries that have limited areas with latitudes of less than 10°, such as Costa Rica, Panama, Colombia, Venezuela, Guyana, Surinam, Ecuador, and most of Peru.

The application of technology

An overview of the productivity of pasture-based beef production systems in tropical Latin America, was given in the papers by Garza, Barcellos *et al.*, Paladines and Leal, Nores and Estrada, Rolón and Primo, Alarcón, Kornelius *et al.*, Serrão *et al.* and Toledo and Morales. As a whole they show that the productivity of native savannas is extremely low, but it can be drastically increased by the introduction of improved grasses such as *Brachiaria decumbens, Panicum maximum* and *Hyparrhenia rufa* in order of increasing native soil fertility. In the case of jungle areas, beef production per unit area is higher than in savannas because of a better rainfall distribution and the fertilizer value of the ash. Nevertheless the productivity of jungle pastures seem to decline more rapidly because of fertility decline and weed invasion. In all cases but one, the introduction of legumes have not been successful for more than a year or two. Thus, the next breakthrough in tropical pasture productivity on acid soils of Latin America is expected to be a result of the strategic use of productive and persistent grass-legume pastures.

Transfer of technology activities through regional trials and training activities are in operation in Latin America, as shown by the summaries from Colombia, Brazil, Ecuador and Panama by Alarcón, Rolón and Primo, Tergas, and Riveros. Progress has certainly been made, but none of the Seminar participants considered these efforts sufficient to close the gap between technology development and technology transfer. The Australian experience of both successes and failures, described by Roberts, is certainly food for thought for pasture specialists in this hemisphere.

AREAS THAT NEED STRENGHTHENING

The most important knowledge gaps identified in this Seminar, either explicitly or implicitly, can be summarized in the following paragraphs.

1. Collection of both grass and legume germplasm should be intensified and better coordinated among the different countries. Given the disease and insect stresses of germplasm near its center of origin, collection of legumes in acid soil regions of Southeast Asia and the Pacific, and of grasses in similar areas of Africa should be intensified for use in Latin America. Of particular concern is the genetic vulnerability of *Brachiaria decumbens* and other species with only one or two ecotypes diffused over the entire continent. Emphasis should also be given to legume browse species, given their importance to animal nutrition in both savanna and jungle areas.

2. As the collecting efforts begin to bear fruit, the breeding of tropical grass and legume species should gain in importance. Breeding for disease and insect tolerance, improved nutritional quality, and tolerance to acid soil stresses are the highest priorities. The limited variability in tropical grass species can be vastly increased when apomixis is broken, such as the case of *Panicum maximum.*

3. The extremely limited knowledge about the nutritional requirements of forage grass and legume species in relation to the soil's native fertility must be increased. Critical nutrient levels for the establishment phase should be determined and quantified in terms of soil tests or plant analysis data on a routine basis. Critical levels developed for crop species are not likely to be useful for pasture species. Forage germplasm should be classified according to its nutritional requirements and grouped into classes defined quantitatively and not, as "adapted to somewhat more fertile soils".

4. Almost nothing is known about weed control in pastures growing in acid infertile soils, including jungle regrowth, as Doll's paper points out. Low input technologies must be developed to cope with these and other causes of pasture degradation.

5. Site-specific work is needed to develop low-cost pasture establishment methods, including improving the native savanna.

6. Very little is known about the maintenance requirements of improved grass-legume pastures, particularly their fertilization needs under different grazing pressures and management systems.

7. There is also very little hard data on animal productivity from improved grass-legume pastures. Liveweight gain trials should be conducted for a sufficient number of years to ascertain persistence and productivity in a meaningful way. Long term trials require good planning, and a commitment of financial resources for several years.

8. Improved grass-legume pastures are expected to cover a certain percentage of the total grazing area. This proportion ranges from 5 to 10% for strategic use in breeding herds to almost 100% in fattening operations close to the markets. Herd management studies are needed to determine the optimal proportion of improved pastures and its relationship to mineral supplementation and other important animal management and health practices.

9. Transfer of technology activities, such as regional trials and training should be intensified and coordinated in a way that the different countries share the experiences of the other ones. Technology transfer begins with technology validation in specific sites and should be strengthened by follow-up contacts between trained personnel, as part of an overall tropical pasture research network.

LITERATURE CITED

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GLOSSARY OF PASTURE SPECIES MENTIONED

GRASSES

Scientific name	Spanish	English	Portuguese
Andropogon			
bicornis L.	*Rabo de zorro*		
gayanus Kunth.	Azul de Rodesia; Carimagua	Gamba grass	Capim gamba
Aristida *pallens*			Capim barba *de bode*
Axonopus			
affinis Chase	Carpeta; zacate amargo	Carpet grass; narrow-leaf carpet grass; nat grass	Grama tapeta; grama jesuita
compressus (Swartz) Beauv.	Grama trenza; caña-mazo; trencilla; zacate amargo; pasto alfombra	Carpet grass; broadleaf carpet grass	Capim-cabayu; Missionera; grama tapeta
micay H. García-Barriga	Pasto micay; pasto chato; cañamazo dulce		
purpusii (Mez) Chase	Guaratara o Guarataro		
scoparius (Flügge) Hitchc.	Pasto imperial	Imperial grass	Capim imperial; Capim Columbia