The Role of *Centrosema*, *Desmodium*, and *Stylosanthes* in Improving Tropical Pastures

*Edited by*

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This integrated collection describes the importance of forage legumes for pasture development and improvement in the tropics and subtropics. Leading agronomists review the magnitude of the need for pasture improvement; tropical and subtropical soil and climate environments; reports of the successful use of legumes in pasture development in a wet and a dry tropical environment; and the scope of the problem in terms of area to be developed and development logistics required. Three legume genera, Centrosema, Desmodium, and Stylosanthes, are discussed in detail—information is presented on taxonomy, adaptation, distribution, productivity, and usefulness—and considerable emphasis is placed on Rhizobium germplasm resources for these genera. A concluding section of technical essays addresses special considerations in using tropical legumes in pasture development and presents a coordinated multidisciplinary approach to legume exploration and evaluation.

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Increasing population and the expanding need for food in the world are placing special responsibilities on agricultural scientists and technicians. Not only must new information and technology be generated but also existing information must be gathered, evaluated and placed in context for its potential and actual usefulness; indeed, without the latter, it may be difficult to select sensible priority areas for the development of new technology. The world need for accurate, useful information that is packaged in a way readily usable by others is great, and the gathering and evaluation of such information should receive high priority for international cooperative effort.

The study presented here is an outstanding example of international technical cooperation. The cooperating institutes were the Australian CSIRO Division of Tropical Crops and Pastures and the University of Hawaii College of Tropical Agriculture and Human Resources, Department of Agronomy and Soil Science. Both are experienced, recognized centers for tropical pastures and tropical agriculture. Other prominent scientists, experts in their own fields, also contributed their knowledge in this publication. Funding for much of the joint study was provided by the Agency for International Development under the 211(d) program.

The final product of this exemplary collaborative effort is a comprehensive but focused overview of the current status and potential use of Centrosema, Desmodium, and Stylosanthes species in tropical pasture systems. This information is further to suggest areas where our knowledge is most limited and further research effort clearly warranted. It is the first document of its kind and it should find a wide application as a major source of information for those interested in food production in tropical areas.

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Interpretive Summary

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INTRODUCTION

In recent years a great deal has been written about malnutrition in third world countries—its undesirability and possible ways of alleviating the problem. Understandably, emphasis has been placed on ways of improving crop production since crops can be consumed by man directly. Energy conversion of renewable resources to human food via the animal in the form of milk and meat is considered less efficient. Despite major technological advances in crop production there is still an important role for tropical pastures based on the forage legume, especially for developing countries.

Legumes are a group of plants that are able to fix atmospheric nitrogen, which in time may become available to the host plant, companion grasses, the soil organic matter, and to the grazing animal. Pasture legumes are used to fulfill a variety of roles. As a forage they can be used to increase animal production. This is especially important in areas with soils of low fertility where cropping is not feasible. Legumes can be integrated into farming systems and used to improve soil fertility for subsequent crops; Dobereiner (1978) calculated that a successful intensive crop production program on the Cerrado regions of South America would consume a staggering 40 percent of the world's current output of nitrogenous fertilizer. In the developing countries forage legumes have been used along roadsides or in village grazing systems to provide low-cost feed for draught animals. Although the introduction of legumes is generally a relatively simple matter, there are many types of tropical environments for which adapted legumes are not yet available. It is relevant to note that most third world countries occur in the tropics.

There are further reasons why less emphasis has been placed upon the development and use of forage legumes. Prior to the world energy crisis and the concomitant rises in fertilizer costs, there was a tendency to hide our ignorance behind a bag of fertilizer; it is easier to increase animal production by applying fertilizer to grass than to develop grass/legume combinations. There is also a novelty factor; many of the advantages of systems based
upon tropical pasture legumes were not documented until the mid-
1960's and, indeed, there is still a dearth of sound research
findings and experience. Finally, we are dealing with rather com-
plex systems involving interactions between soil-pasture-animal.
It is therefore more difficult to appreciate the value of grass/
legume systems in terms of inputs and outputs. Not surprisingly
there are many misconceptions about the potential worth of tropi-
cal legumes in pasture systems.

SCOPE OF CONTRIBUTIONS

This series of essays describes the need for, and the value
of forage legumes to, pasture development and improvement in the
tropics and subtropics. The essays are divided into three sec-
tions. Section I provides an overview of tropical pasture im-
provement, the soil and climatic environments, reports of the
successful use of legumes in pasture development in a wet and a
dry tropical environment, and the scope of the problem in terms of
area to be developed and the logistics required to further im-
provement. Section II deals with three legume genera chosen for
their actual and potential contribution to pasture improvement.
These genera are discussed in detail--taxonomy, adaptation, dis-
tribution, productivity and usefulness as pasture plants. It is
the general feeling of the authors that the pasture potential of
the three genera has hardly been touched. Each of the three gen-
era contain many more species than have been evaluated for their
contribution to pasture development. Included in Section II is a
statement about the Rhizobium resources that must be evaluated
concurrently with their associated legumes. Any deviation from
concurrent evaluation with associated legumes too frequently leads
to disappointment and to the rejection of the legume as a poten-
tial contributor to pastures. Considerable emphasis is placed on
the necessity to collect legumes and associated root nodules con-
taining Rhizobium at the same time. Section III consists of a
number of technical essays related to pasture development, includ-
ing soils, Rhizobium, social and economic considerations and a
coordinated multidisciplinary program for legume exploration and
evaluation.

The contributors have limited their discussion to tropical
and subtropical pasture development in those regions of the world
having four or more months of rainfall. They rarely refer to the
vast arid and semi-arid regions of the tropical world. The essays
have been limited to only three legume genera. It should be
pointed out that in Latin America Roseveare (1948) listed over 100
legume genera and more than 400 species. The three genera--Cen-
trosema, Desmodium, and Stylosanthes--were chosen for their wide
range of adaptation and utilization in tropical pastures.

Grasslands of the tropics and subtropics with a four-month or
more rainy season comprise over 1048 million hectares and have an
average productivity varying, according to region, from 7 to 57
tonnes of beef per 1000 hectares. Conservative estimates are that
a five-fold increase in productivity is a reasonable expectation
for improved pastures. The contributors emphasize the fact that most of these lands suitable for grazing are unsuitable for intensive crop production and that the only way we can make use of this valuable resource is through the grazing animal which, par excellence, is a suitable collector and efficient convertor of grassland plants into a product suitable for human consumption. The legume has to be part of these grasslands as it provides adequate dietary protein for the animal, and its associated Rhizobium fix large amounts of nitrogen each year. Conservative estimates are that on the order of 100 to 200 kg per hectare are fixed each year by the legume/Rhizobium association. This represents from $US 60 to $US 120 of fertilizer nitrogen equivalent. Such contributions cannot be ignored or overlooked considering the high cost of producing nitrogen fertilizer and the increasing scarcity of energy for its production.

The impetus for improvement of tropical pastures is derived in a large degree from the success of the CSIRO Division of Tropical Pastures in Queensland, Australia. In areas where animals on native pasture lost considerable weight during the dry season and took from four to six years to reach market weight, and where calving percentages were well below 50 percent, the introduction of legumes into existing pastures reduced weight losses and even provided a net gain during the dry season and doubled or nearly tripled the conception rates of livestock. Such success has increased the interest in the further development of large areas of the tropical world.

The essays discuss the need for pasture legumes and provide valuable insights for their proper evaluation. They stress the need to evaluate potential legume species under environmental conditions similar to those from which these plants originated. This is emphasized by several contributors who provide examples where alkaline-soil-adapted legumes failed in acid soil environments and were discarded only to be reevaluated years later in the proper environment and are now proven to be useful pasture plants. It is necessary to know the limits of the climate and soil environments of the areas chosen for improvement. Once these are known, then, and only then, should legume collections be made in those parts of the world in which similar soil and climates occur and which are known to have legumes that might be utilized in the new areas. The contributors emphasize the fact that adequate information concerning the collecting site be obtained along with the legume and its root-nodules. This includes a good description of the site, the soil, and the climate. The root nodules must be collected to ensure that the associated Rhizobium necessary for nitrogen fixation are brought to the new regions where they do not exist. Without the proper Rhizobium many potentially useful legume introductions have been discarded in preliminary evaluation trials. It is absolutely necessary to test acid-soil-tolerant legume strains in acid soil environments and alkaline-soil-tolerant legumes in alkaline soil environments. The contributors point out the fact that there are strain differences within the same legume species. *Stylosanthes hamata*, for example, has strains adapted to acid soil environments as well as alkaline soil environments. The alkaline-
Soils-adapted strains do not grow well in acid soil environments and vice versa. Preconceived notions that these genera are specifically adapted to either wet or dry environments is erroneous and is based primarily on the adaptation of the few lines evaluated. Centrosema has been described as being well adapted only to warm-humid regions of high rainfall. This is not so. There is a tremendous amount of variability within the genus. Although Centrosema pubescens is primarily adapted to the wet tropics, it has been collected from 500-600-mm-rainfall regions on the southern margin of the Guajira Peninsula of Colombia and from areas above 1000 m altitude near Santa Cruz, Bolivia (18°S).

The contributors emphasize the need for the development of an international germplasm center where collections can be kept and catalogued according to standard procedures. They point out that national, regional, or local conditions seldom permit widespread testing and evaluation and that quite often materials that are tested locally fail to perform well and are discarded when, in fact, they may be suitable in different environments. It is difficult if not impossible for any one research center to maintain materials that are of no current practical value, hence the need of an international center to perform the function of long-term maintenance and storage. Without such a facility, we are not going to be able to meet the ever-expanding need for food in future years. There is an urgent need for well-organized, multidisciplinary collection programs to be established in the near future in order to rescue germplasm from areas that are rapidly being taken over by expanding rural and urban development. Many valuable collection sites will be overrun and germplasm lost if concerted efforts are not made to collect these materials. Proper collection and evaluation procedures must be followed. The contributors emphasize the urgent need for botanical/taxonomic evaluation in conjunction with agronomic evaluation. Botanically, these genera are not well defined and have been poorly collected; existing collections do not contain specimens of all the species that were collected and in fact are highly truncated, so much so that they do not cover the range of variation present in the species described. Consequently, agriculturalists using existing taxonomic descriptions become puzzled and are quite often confused as to the proper nomenclature; in the evaluation procedures, they often add to the existing confusion. A strong plea is made for a multidisciplinary approach for collection procedures and for taxonomic and agronomic evaluations. Such an approach requires a team effort—a team composed of taxonomists, agronomists, and ecologists—using modern computational techniques for complex analytical procedures to provide adequate interpretation of data.

In evaluating plants for pastures, primary criteria are animal performance and the ability to persist in difficult environments under a wide range of management conditions. It is recommended that accessions are not discarded if they are found wanting. Quite often they may have other valuable attributes such as disease, insect, and drought resistance that may be transferred to more desirable agronomic species through breeding programs.
Although these essays are limited in scope, we hope that sufficient interest will be stimulated to carry out intensive research programs in tropical legumes for pasture development. Tropical pasture legume development in much of the world is in its infancy (the number of released cultivars of *Stylosanthes* species can be counted on the fingers of both hands), whereas the number of released cultivars of a temperate legume such as white clover (*Trifolium repens*) has many cultivars available, which were developed for specific regions.

CONCERNS AND OBSERVATIONS

We shall not attempt to list our concerns and observations in order of priority for two reasons. First, we are to some extent dealing with an unknown situation; priority listing would thus tend to be subjective. Secondly, interested bodies will tend to have their own priorities determined by logistical commitments—staff, equipment, and so forth. We shall simply, therefore, list areas that warrant further study, the order in which they appear being determined by the order in which the subjects arose in various sections.

Taxonomy and Description

In tropical pastures we are largely, but not exclusively, dealing with a system in which legumes from South and Central America are being mixed with African grasses and sown throughout the widely scattered tropical world. Good communication between workers in the field is essential; taxonomy provides the basic language for communication.

We have seen that there are parts of the system that are malfunctioning, and there are several reasons for this. Sometimes, as in examples mentioned above, we have the same plant material given different taxonomic names—somebody in Africa cannot find anything in the Australian literature about *Stylosanthes bojeri*; the name has been superseded, first by *S. mucronata* and then by *S. fruticosa*. Although relevant work is being done, he does not have access to it. There is an urgent need to revise genera that are now of tremendous importance in the tropics. In doing so, taxonomists should be aware of the needs of agronomists. Tropical species can be very diverse, containing forms adapted to a wide range of climatic and ecological conditions in addition to displaying an array of agronomic phenotypes. At least some of this information should be built into taxonomic descriptions.

Plant Collection

We have already commented about the deficiencies in this area; however, we note that information obtained at the time of collection can be useful in predicting areas in which the material might be useful.
Rhizobial Collection

Legumes need to be associated with rhizobia if they are to fix nitrogen. There are two alternative strategies to ensure this. First, select plants that function effectively with the local rhizobia; this cuts down costs and may be particularly appropriate for rangeland development. Secondly, inoculating seed before sowing provides immediate benefits although it may not be long-lasting. Rhizobia inoculation would, however, be very appropriate in a cropped situation and may be necessary in areas in which certain legumes have not been grown previously (e.g., introduction of some Centrosema spp. into Africa). Recent evidence suggests that different soils may be associated with specific types of rhizobia and so it is essential that legume collections in the field must also involve sampling the local Rhizobium.

Adaptation--General

Different legumes are adapted to different edaphic and climatic conditions; a species that grows well in one set of conditions may die in another. It is important that we carefully document the various conditions leading to better legume survival in a new environment. With this information the chances of sowing persistent legume pastures are enhanced.

If such work is to be undertaken then we need to rethink the strategies available to us. We can, for example, use information from Stylosanthes to illustrate this. In Australia, with soils in the neutral pH range both S. capitata and some forms of S. hamata fail. S. scabra and the acid-loving form of S. hamata survive and are selected for commercial distribution. In the Llanos, with soils of very low pH, S. capitata thrives and emphasis is placed on this species but the alkaline form of S. hamata performs poorly and S. scabra is decimated by stem-borers. In the West Indies, only the alkaline form of S. hamata survives on alkaline soils. Each institute, therefore, selects different material for its own purposes, which may be quite different from those of other areas. It is therefore necessary to establish relevant 'gene' pools, systems of communication (including plant descriptions), and methods of selecting the material for study. Methods for integrating the resultant data are already available.

Adaptation--Soils, Climate

As the intensive study of tropical legumes and of their introductions is relatively recent, we have very little information on their adaptive characteristics. Although, for instance, we find that Stylosanthes is regarded as being suitable for infertile conditions and Centrosema for more fertile situations, there is little documented evidence to confirm these 'facts'. Most of the information on legumes comes from agronomic or mineral nutrition experiments carried out with a narrow range of genetic material. Similarly, we have little information on the physiology of these plants.
There are two well-known complementary methods of improving plant adaptation: by plant introduction (utilizing material adapted elsewhere) and by plant breeding.

To date, plant introduction has provided all but one of the commercially available tropical legumes. Provided suitable programs are undertaken, this is a less costly, fast way of providing plants. There are many areas for which adapted plants are not yet available, and so an introduction program would be preferable before attempting plant-breeding programs. In some instances, where there are reasonable collections of the species of interest and where objectives can be clearly defined, plant introduction may reach a stage of diminishing returns.

This situation will become increasingly common as our collections grow. There is a need to prepare for this time by examining genetic relationships within some of the species and genera of interest; this knowledge will expedite required plant-breeding programs.

REFERENCES


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Section I
The Improvement of Tropical Pastures
The developing countries (located largely in the tropics and subtropics) have had difficult problems in the 1970's, but some progress has been made. Per capita food production by individual countries has not greatly increased in that period; because although total food production has improved, it has not exceeded the rate of population increase. Total arable lands increased in area about 4 percent between 1970 and 1978, but total population increased about 19 percent during the same period.

Raising the agricultural output on arable lands, is indeed possible, as numerous local or regional tests on the value of improved technology and superior management have demonstrated, particularly in crop production. The additional potential for increasing total agricultural output, by bringing new grazing lands into production, and by significantly improving the feed supplying power of such grazing lands may be more effective in raising agricultural production than focusing attention only on arable lands. Improving the pastures established on all those grazing lands that are not suitable for crop production, has received little attention. This volume explores the dimensions and nature of tropical pasture improvement for the production of ruminant livestock for their meat and milk products for man's benefit.

A major factor in pasture improvement is the introduction and successful management of permanent legume species in mixed swards of adapted grasses and legumes. The total benefits of utilizing adapted legumes are still being explored, but the results of research and field experience to date may be summarized as follows: (a) legumes substantially increase total feed production, (b) legumes fix large amounts of nitrogen through the action of their root nodules, and thus may largely or completely obviate the need for nitrogen fertilizers, (c) the mixed grass-legume forage is much richer in protein than grasses alone and provides balanced nutrition to grazing livestock, (d) mixed sward is effective in progressively enhancing soil productivity, with additions to the soil organic matter and concurrently producing a more mellow soil structure, and (e) mixed sward is generally more effective than grasses grown alone in controlling rainfall runoff and in providing resistance to soil erosion.
It should be stressed that in order to obtain these important benefits from the use of permanent legumes-grass pastures we require an understanding of their growth requirements relative to the requirements of the grazing animal. The wide ranging reports of research on the permanent forage legumes that are summarized in this volume, provide a basis for such effective management. When widely implemented, improved pastures should prove an important method of increasing total agricultural productivity on land not suited for cropping. This should contribute significantly toward attaining the self-sufficiency in food production desired by every developing country.