A RELEVANT APPROACH TO IDENTIFYING WELL ADAPTED AND PRODUCTIVE FORAGE LEGUMES FOR TROPICAL THIRD WORLD COUNTRIES

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ABSTRACT

In many parts of the Third World tropics, very little systematic work has been conducted to identify plant material suitable for legume based forage systems. Some programmes have faltered because of the assumption that cultivars and lines identified as superior elsewhere, will grow well in other environments and management systems.

The risk of failing to identify suitable plants is reduced by working with a broad genetic base and a knowledge of the environments in which introductions have been collected or previously tested.

Given typical restraints of limited time and resources, conventional approaches to evaluation may not be valid. Many detailed measurements can be omitted in programmes which place introduction nurseries under a succession of different management practices, to obtain several suites of information.

Investigative development closely integrates research with the establishment of legume based forage systems on farms. In this approach these improved forage systems have several roles: as a resource for the farmer, an extension tool in the farming community and to identify or verify relevant and effective methods of establishment, management and utilisation of selected cultivars and lines.

Additional Key Words: Plant collection, plant characteristics, adaptation, multi-purpose nurseries, investigative development.

INTRODUCTION

In recent years there has been an increasing awareness that the use of well adapted and productive forage legumes is often the key to increasing livestock production in the tropics. This provides a most valid basis for fragile Third World economies to become more self-sufficient in animal products with a sounder economic future for their livestock farmers.

In many regions of the Third World tropics very little systematic work to identify plants for legume-based forage systems has been successfully conducted.

Introduction programmes have often been indiscriminate. Either little or no information was available concerning the area from which introductions came, or it was ignored, so that many were tested in areas in which they were virtually certain to fail (Williams and Burt, 1982). Other programmes have faltered because of the assumption or hope that cultivars and lines identified as promising in other evaluation programmes will do well in a range of new environments and systems. Even where other centres of research have identified promising plants for similar environments, a decision to evaluate only a narrow range of recommended material can place the programme at risk because of differences in the pest/disease complex and the types of forage system within which plants will be utilised.

In some situations in the Third World tropics, we are still faced with answering the most important question about each accession being tested, namely: "Does it survive?" — and eventually, just how well it "fits" a range of environments with a minimum of inputs such as fertiliser and water. The risk of failing in this goal is reduced by working with a broad genetic base which nevertheless can be sensibly tailored right from the beginning by using the knowledge of the environmental adaptation and agronomic potential of the germplasm being considered for testing.

There is now evidence (Burt *et al.*, 1975), that the most successful introductions have come from areas with a climate more stringent than that for which they are required. This is not a major difficulty. If areas of approximately similar climate (homoclimes) can be found, it is usually possible to recognise adjoining areas with somewhat more stringent climates.

A plant responds to more than climate however. Its success depends on edaphic responses, its reproductive ability, ability to spread and invade disturbed ground, its response to grazing, trampling and burning and similar factors (Burt *et al.*, 1979). Obviously then, the most valuable plant collections are those where the collector has recorded sufficient ecological and environmental data at the collection site to enable their characterisation in terms of environmental adaptation, species compatability and animal acceptance (Reid & Strickland, 1983). In many forage collections however, a great number of accessions are listed only by their country of origin, all other data having been lost or not recorded (Reid & Strickland, 1983). The value of these accessions to projects involved in identifying well adapted material is therefore greatly reduced.

Criteria for effective forage plant collection have been outlined by Reid & Strickland (1983). These authors stressed the need for a detailed knowledge of the flora and geography of the proposed plant source region and careful planning and research so that the timing of the visit coincides with the availability of ripe seed.

A comprehensive list of environmental attributes which can be recorded at collection sites has been presented by Reid & Lazier (1979). A number of plant collection agencies have developed standardised precoded descriptors that can be used by collectors, in the field (Reid & Strickland, 1983). Their use reduces ambiguities and allows for the use of a common language which improves the international value of the collection. Its international value is also improved if it is shared with large centres of research to ensure long-term storage and to enhance its value to other forage improvement programmes.

However, the evaluator should be aware that whilst well planned and executed new plant collections, both locally and in other countries, may be of considerable value, they will seldom be necessary nowadays to ensure that suitable forage plants are identified in evaluation programmes. There are now many existing germplasm collections held by major forage plant groups that may be utilised for immediate screening and evaluation (Reid & Strickland, 1983).

In this paper, the Caribbean Agricultural Research and Development Institute's (CARDI) Forage Legume and Pasture Utilisation Project in Antigua is described to illustrate some aspects of a relevant approach to identify well adapted and productive forage plants for tropical Third World livestock systems.

THE CARDI FORAGE LEGUME PROJECT

The CARDI Forage Legume and Pasture Utilisation Project was initiated on the island of Antigua in 1974. It has had several objectives:-

1. To identify well adapted and productive forage plants for drier parts of the Caribbean.
2. To produce bulk seed of the selected lines.
3. To formulate and demonstrate locally relevant forage systems.
4. To identify and demonstrate establishment and management practices to enable selected plants to be optimally utilised in these systems.
5. To assist in the establishment of legume-based systems throughout the region, including seed supply, advice and training of local staff.

The intensive evaluation programme involved measurement of more than 100 grass and 300 legume accessions grown in nearly 2,000 research plots, on 5 edaphically contrasting sites. Greatest emphasis by far was placed on fine-textured, high pH soils since it was internationally recognised that very few or no forage legumes could be confidently recommended for long-term pasture improvement on such soils in the tropics and subtropics. The programme was designed to enable a broad description of their climatic and edaphic suitability and agronomic potential, a key theme being identification of accessions which grew well in the major edaphic zones with a minimum of cultural inputs.

Whereas most of the grasses tested originated in the grasslands of East, Central and South Africa, nearly 75% of the legumes tested were actually collected by the project in the Caribbean and Yucatan Peninsula of Mexico. More than 400 accessions were collected, most of which were also sent to other centres of pasture research in the tropics and subtropics. The Yucatan collection comprising 243 legume accessions representing 23 genera and 37 species, has become increasingly recognised internationally as a very valuable source of germplasm for developing improved forage systems on fine-textured, high pH soils in the tropics and subtropics (J.R. Lazier, International Livestock Centre for Africa, pers. comm). A complete list of species is available from the author. The Caribbean collection of *Stylosanthes hamata* which contains ecotypes adapted to alkaline black clay soils could be a valuable source of cultivars for the vast areas of similar soils in the dry tropics of India and Africa (Edye and Grof, 1983).

Most of the other material tested was supplied by the CSIRO, Division of Tropical Crops and Pastures while valuable material was also sent by the International Centre for Tropical Agriculture (CIAT), Colombia, and the University of Florida, Fort Pierce.

To demonstrate some aspects of the evaluation approach used, the programme to identify well adapted and productive forage legumes for calcareous clays in drier parts of the Caribbean will be summarised. Similar programmes to identify suitable grasses for calcareous clays, and legumes, grasses, and legume/grass associations for deep cracking clays were also conducted.

Nursery Evaluations

1. *Testing programme on a shallow calcareous clay.* Two replicates of 186 accessions representing 15 genera and 36 species were established as healthy, nodulated transplants spaced at 1 x 1 m in plots ranging from 2 x 4, to 4 x 4 m. Plot size was dependent on the amount of planting material available. Included were accessions collected in areas with more stringent climates than the testing sites, namely, the islands of Curacao and Barbuda and parts of the Yucatan Peninsula. First plots were established in February, 1976 and the final ones, nearly 12 months later, incorporating newly collected Yucatan material. For the first 12 months all accessions were carefully weeded and were then left to compete with any invading species. Plots became dynamic mixtures of resident legume accession and invading grasses and legumes. Initial defoliation management was also aimed at enhancing establishment, growth and development. From February 1976 until April 1978 (Regrowths 1-9), lenient cutting management was imposed with some long rest perids to enable seed collection from promising accessions. Cutting height was adjusted selectively to differences in growth habit. In April 1978 the whole area was converted to a grazed nursery. Until October 1981 (Regrowths 10-20) it was mainly rotationally grazed with 300-400 sheep and goats but with some deliverate overgrazing from 1980 onwards and some topping to reduce dead material buildup. Finally, in 1982 the nursery and an adjoining grass evaluation area became an intensive farmlet for a small ruminant enterprise.

Attributes measured included dry matter (DM) yields, plant vigour (visual), spread, stage of growth, insect and disease damage, utilisation by small ruminants, persistance under grazing and contribution to sward composition.

After 18 months of evaluation the earliest planted accessions (112) were delineated into 10 relatively distinct groups using "Grouper", a diagnostic pattern analysis programme (Lance *et al.*, 1968). "Grouper" separated the accessions with a series of hierarchical dichotomies based on the most significant contrasts in their growth attributes. This classificiation provided a valuable guideline when deciding what species showed sufficient promise to warrant the assembly of a broader genetic range for further testing on a deep calcareous clay site.

2. *Testing programme on a deep calcareous clay.* Two replicates of 145 accessions, representing 13 genera and 31 species were established as healthy nodulated transplants spaced at either 1 x 1 or 0.5 x 0.5 m in plots ranging from an extreme of only 1-2 plants, to 4 x 3 m. Greatest emphasis was placed on new accessions of four species which had shown promise on the shallow site, namely, *Clitoria ternatea, Macroptilium atropurpureum, Neonotonia wightii* and *Stylosanthes hamata.* First plots were established in April 1978 and the final ones in October 1978. For the first 12 months, all assessions were carefully weeded and were then left to compete with any invading species. For the duration of the assessment period (April 1978-April 1982), lenient cutting management was imposed, with some long rest periods to enable seed collection from promising lines.

Attributes measured included DM yields, plant vigour (visual), chlorosis level, stage of growth, insect and disease damage and sward composition.

RESULTS

Several suites of information were rapidly and usually simply obtained from both trial sites, to produce a relatively clear picture of the growth characteristics, adaptation, productivity, persistence and agronomic potential of each accession tested. For example, information on the persistence and competitiveness of each accession under grazing was obtained by visually assessing level of dominance within each plot over a three year period. These data summarised in Table 1 for each species, were valuable when deciding on the most suitable accessions for long-term pastures. Thus, superior accessions of *Leucaena leucocephala, Macroptilium atropurpureum, Neonotonia wightii, Stylosanthes hamata* and *Teramnus labialis* were chosen for bulk seed production.

The range of adaptation to high pH, calcareous soils proved to be almost as high within some species as that between them. This was particularly so for *Macroptilium atropurpureum* as reflected by the range of iron chlorosis in the 43 accessions measured on the second site. Assessments made in the first year, indicated that 31 accessions showed little or no iron chlorosis (i.e. were well adapted), 5, slight to moderate (moderately well to marginally adapted), 4, high (poorly adapted) and 3, so severe, that necrosis was occurring. All 7 accessions showing high or severe chlorosis died out in less than 2 years.

This information clearly showed that the commercially available cultivar "Siratro" represented only a small part

TABLE 1: Changes in legume dominance (0-5)* under grazing from January 1979 until October 1981.

Species	Jan 1979	July 1979	Nov 1979	June 1980	Oct 1981
Centrosema virginianum	0.8	1.4	0.4	0.8	1.1
Clitoria ternatea	2.3	1.4	1.1	0.4	0.2
Desmanthus spp.	1.8	2.6	1.0	1.7	1.5
Desmodium tortuosum	4.8	4.5	4.0	1.1	0.4
Galactia spp.	1.2	1.4	0.0	1.1	0.5
Leucaena leucocephala	5.0	5.0	5.0	4.0	0.8[1]
Macroptilium atropurpureum	3.8	4.9	4.1	2.5	2.8
Neonotonia wightii	4.8	4.8	4.5	3.4	2.8
Rhynchosia spp.	1.2	1.0	0.0	0.0	0.0
Stylosanthes hamata[2]	3.1	3.3	2.1	1.7	2.3
S. calcicola	1.0	1.0	1.0	1.3	1.5
Teramnus labialis	2.6	3.2	3.4	2.6	2.4
T. uncinatus	0.5	1.0	0.0	0.0	0.0

* 1.0 = present; 2.0 = frequent; 3.0 = subdominant; 4.0 = codominant; 5.0 = dominant.

[1] Selectively overgrazed by goats.

[2] Excluding "Venezuelan" types.

Species that did not persist until 1979: *Calopogonium caeruleum; Centrosema pubescens; C. schiedeanum; Desmodium dichotomum; M. lathyroides; Phaseolus lunatus; S. hamata* ("Venezuelan" types); *S. guianensis; S. ingrata; S. scabra; S. viscosa.*

of the genetic variation for adaptation to calcareous clays within this versatile species. The level of chlorosis of all accessions was almost certainly strongly correlated with the edaphic conditions of their collection sites but unfortunately insufficient plant collection information was available to test this hypothesis fully. However, the excellent adaptation of all accessions collected in the Yucatan Peninsula reflected the high-pH limestone-derived soils and relatively severe dry season of this centre of origin.

Similarly all *Stylosanthes hamata* accessions from the Caribbean Islands (including Curacao) and Florida, as well as CPI 40264A (Bahia, Brazil), CPI 49080 (Baranquilla, Colombia), and CPI 61670 and 61671 (Paraguana Peninsula, Venezuela) were collected on intermediate or high pH soils and all were well adapted edaphically to calcareous clays. Conversely, all "Venezuelan types" (cv. "Verano" and CIAT 118, 122 and 147) were collected from acid soils and all were poorly or marginally adapted.

Investigative Development

In addition to the information from the multi-purpose nurseries, further information on adaptation, management responses, and persistence was obtained from demonstration, on-farm forage systems incorporating mixtures of promising legumes and grasses. These systems were always designed to enable further evaluation of plant material as well as to improve livestock feeding systems for the farmer. Such information was included with the nursery data to characterise all species tested under the headings outlined in Table 2.

TABLE 2: Parameters to describe the growth, adaptation and agronomic potential of forage legumes tested on calcareous clay soils.

1. Typical life cycle of individual plants in this environment: — Annual; biennial; short-term perennial; perennial; too poorly adapted to establish or to persist beyond the first season.
2. Growth form(s): — Herbaceous; semi-woody; woody shrub or tree; non-climbing; scrambling, weakly twining; climbing, strongly twining.
3. Edaphic adaptation: — low; moderate; high.
4. Drought tolerance: — low; moderate; high.
5. Agronomic potential for calcareous clays in drier parts of the Caribbean: — negligible or none; low; moderate; high.
6. Recommended use(s) in this environment if seed was available: — short-term pastures; permanent pastures; cut and carry systems; protein feed banks; protein/energy feed banks; no recommended use.
7. Grazing tolerance of species recommended for forage systems: — tolerant of prolonged hard grazing; requires lax grazing or long regrowth periods; intermediate.
8. Accession(s) chosen for bulk seed production.

CONCLUSIONS AND RECOMMENDATIONS

From the analysis of this project and from other relevant tropical experience and data, the following guidelines are proposed to encourage the use of appropriate strategies to identify well adapted and productive forage plants for tropical Third World Countries.

1. Before initiating a programme to identify suitable plants for new regions and forage systems, every effort should be made to assemble cultivars and lines collected in or selected for similar edaphic, climatic and management conditions. A broad genetic base of plant material can be selectively assembled if the evaluator has access to good environmental information on collection and selection sites. Consequently, a great deal of time and effort can be saved by avoiding testing a large number of poorly adapted accessions.
2. A testing programme requires only small experimental quantities of seed initially. This should not be sown directly. Healthy, well nodulated legume seedlings should be transplanted to ensure that each accession can express its adaptation and growth characteristics. Failure to establish from seed is a cultural problem, not an expression of adaptation to the environment. Since most tropical legumes are self pollinated, accessions can be tested when as few as 1-2 seeds are available; plot size need not be uniform!
3. It is not essential to establish all accessions in a nursery, at the same time. As new accessions become available, they can be added to nurseries for up to about a year with very little bias in long-term programmes.
4. Given the typical restraints of limited time and funding, evaluation programmes must be geared towards identifying well adapted and productive accessions simply, and yet effectively, so they might be used in relevant improved farm-forage systems as soon as possible. These restraints alone may invalidate the use of conventional approaches to evaluating forage plants which involve a chronological sequence of separate stages from spaced-plant introduction nurseries to grazing trials. Several stages and many detailed measurements can be omitted in programmes which place introduction nurseries under a succession of different management practices to obtain several suites of information. Multi-purpose nurseries should be retained for as long as possible, even if they eventually do nothing more than provide information on the long-term persistence of accessions under grazing. When the main objective is to identify accessions for long-term forage systems, short-term herbage production information should be interpreted with care. Attributes such as survival, persistence and spread should be given high priority and therefore programmes should be long-term.

   For at least one year, plots should be leniently managed and well looked after, to enhance establishment and expression of growth characteristics and adaptation. After 1-2 years they should be turned into grazed nurseries with management varied to provide a broad picture of plant response to grazing and utilisation by animals. Nurseries can also be used to multiply seed from promising accessions.

5. A high proportion of evaluation to identify superior accessions can be done with visual assessments. When resources and time and information are limited, it is often more relevant to visually assess limited replicates of broad ranges of plant material on several contrasting sites, than to assess well replicated but narrow ranges of material in a central nursery, using laborious harvesting, weighing and botanical separation techniques.
6. Analysis of variance may be less appropriate than numerical classification and ordination-type programmes to handle a complex mass of data from large populations of accessions (Williams, 1983).
7. Investigative Development. The integration of problem solving and plant characterisation with development and demonstration (extension) work is particularly valuable if an increasing emphasis on the latter aspects of a forage programme begins to dilute research efforts. Thus, farm-forage systems can be multi-purpose: to provide an improved livestock feeding system tailormade to individual farmer needs and resources, as an extension tool within the farm community, to provide information on methods of establishment, management and utilisation of selected accessions and to supplement nursery information used to characterise such accessions.
8. Herbage quality determinations should only be conducted on 'selections' that have at least moderately high agronomic potential. A great deal of time and money is wasted if quality assessments are done on accessions which subsequently prove to be agronomically unsuitable. Furthermore, extrapolation of quality information from large centres of research, plus field assessments of utilisation by animals, will often be the most relevant method for smaller projects to sensibly decide on the suitability of species and lines as livestock feed.
9. Leadership style can have a profound influence on the effectiveness of a project. Choice of a leader is a critical decision, especially in small, isolated projects. It is the opinion of this author that all too often agricultural projects in the Third World tropics are hampered by leaders whose style is to direct field operations mainly from the sanctuary of an office, within the framework of a conventional hierarchical authority structure. The relevant alternative is to lead by example in the field so that staff inherently feel they are working with him, not for him. His objective should be to foster a strong cooperative team effort from staff who have a pride in their work and therefore a conscience about their performance and that of the project as a whole.
10. Relevant forage systems may well be improvements on those already used, rather than new systems. Projects aimed at eventual changes in concepts and systems in order to improve livestock production and efficiency, will usually have to be very long-term in order to succeed. Success has only occurred when improved systems are a natural and socially accepted part of the farmer's everyday life; systems that he understands and respects. It is ludicrous to expect short-term technical projects to solve problems that are a complex of social, cultural, economic and technical influences.

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