PROBLEMS AND SUCCESSES OF LEGUME-GRASS PASTURES, ESPECIALLY IN TROPICAL LATIN AMERICA

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ABSTRACT

Successes and failures of improved legume-grass pastures, mainly in Australia, Brazil and Central America are discussed. Current technology used in pasture improvement is inadequate in a number of tropical areas. Further research is needed to develop new techniques which farmers will be prepared to adopt for increasing their pasture and cattle production. Some of the main problems include: lack of knowledge of soil nutrient deficiencies, lack of well adapted legumes with pest resistance and tolerance to highly acid soils, legume seed inoculation, selection of grasses, dry-season forage, reducing pasture establishment costs, and adequate seed supplies of legume and grass cultivars.

It has been estimated by CIAT (7) that tropical America has 850 million ha of acid, infertile Oxisols and Ultisols where pasture and cattle productivity can be increased markedly when all regions have dependable legume-grass systems. The major part of this vast area is in Brazil, but other countries especially Colombia, Peru and Venezuela have significant tracts of these infertile acid soils awaiting improvement. With increasing population pressure in most countries, any Oxisols and Ultisols suitable for cultivation will be cropped, often in rotation with short or long-term pastures. For example in Goias State, Brazil, where extensive areas of upland rice are grown on poor acid soils, a pasture phase is initiated on a number of farms by planting the rice with a small amount of *Brachiaria decumbens* Stapf. seed; this vigorous grass gives a relatively high producing pasture following the rice crop.

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Even when suitable tropical pasture technology is available for all the acid soil regions, the proportion of improved pasture to unimproved savanna, grassland and forest will probably remain quite low for many years due to economic, political and other reasons. Thus it is necessary to find how to integrate improved and unimproved pasture to maximize production from cattle herds.

The main aim of tropical pasture technology must be to stimulate production of low cost, good quality beef so that meat remains a significant part of the diet of the large numbers of lower income people in tropical America. Improved pastures and their management on a large, rather than small scale is more likely to keep beef prices down. This is because of increased efficiency of larger scale operations from their greatly increased throughput of cattle per unit of resources including land, breeding herd, equipment and improvements, finance and labor. The Banco de Mexico has encouraged and financed large scale pasture improvement and cropping among peasants by its ejido or cooperative scheme in areas of the Mexican tropics.

SUCCESSES AND FAILURES OF CURRENT TROPICAL LEGUME-GRASS TECHNOLOGY

Existing tropical pasture technology (10, 11, 25, 28) has resulted in a number of successful improved pasture developments in Australia, Africa, Brazil, Mexico and other tropical regions. However, for various reasons there have also been a number of failures. There is a lot of research still to be done, particularly in the acid soil areas of tropical America. The pasture problems facing organizations like CIAT, ICA, EMBRAPA, FONAIAP, IVITA and INIAP are urgent and challenging. Where improved legume-grass pastures have persisted there has often been no attempt to monitor the increased profitability and animal productivity.

In this brief review it is impossible to include all my field observations on tropical pasture improvement. Colombia is covered by other seminar speakers. After a short introduction on Australian experience most of my comments will concern Latin American countries like Brazil and Mexico where substantial areas of tropical pastures have been sown. A number of countries including Venezuela have not yet made systematic attempts to capitalize on their potential for increasing pasture and cattle productivity.

Australia

In Australia there have been a number of reports of increased cattle productivity from improved pastures. The long-term pasture experiments of Mannetje (18) at the CSIRO Narayen Research Station on poor acid granitic soils (Alfisols) with a summer rainfall of 700 mm and 7 to 7.5 months dry season exemplifies what can be achieved in the extensive *Heteropogon contortus* (L.) Beauv. ex Roem. & Schult. region of central Queensland, which is the most important beef cattle area in eastern Australia. Mannetje (18) found that unimproved native *H. contortus* pasture will carry 0.27 steers/ha and give a liveweight gain of 25 kg/ha. Fertilizing the native pasture with 125 kg/ha of molybdenized superphosphate did not improve stocking rate and only increased liveweight gain to 34 kg/ha. However replacement of the native pasture with the legume *Macroptilium atropurpureum* (D.C.) Urb. cv. Siratro and *Cenchrus ciliaris* L. in conjunction with 125 kg/ha of molybdenized superphosphate, raised the stocking rate to 1.09 steers/ha and gave a mean liveweight gain of 147 kg/ha. The Belmont Red and Hereford steers were marketed at about 24 months of age and gave first quality carcasses of 250 kg. This is a very substantial increase in productivity compared to that from unimproved native pasture: 4 times the stocking rate and almost 6 times the meat yield. Of considerable importance is the fact that the legume *M. atropurpureum* cv. Siratro has persisted and multiplied in Mannetje's (18) pastures which have improved their productivity over 10 years. Similar results have been achieved on commercial farms.

On the wet tropical coast of north Queensland where rainfall is 2000-4000 mm/yr, mixed pastures of the legumes *Centrosema pubescens* Benth., *Pueraria phaseoloides* (Roxb.) Benth. var. javanica (Benth.) Bak. and *Stylosanthes guianensis* (Aubl.) Sw. with *Panicum maximum* Jacq. have been very successful for beef production. With applications of 250 kg/ha/yr of superphosphate and correction of Mo, Zn and Cu deficiencies, these pastures will carry 3 to 4 steers/ha/yr and give liveweight gains up to 900 kg/ha/yr (29).

Brazil

Brazilian farmers with encouragement from government, and state scientists, and the banks have made an impressive attack on tropical pasture development over the last 7 to 8 years. Extensive areas of improved pasture have been planted in the Cerrado, Amazonia and other regions. Even though failures have occurred, enough successes have given confidence in the future of improved pastures in Brazil, and a high level of new plantings has been maintained. Brazil has planted much larger areas than any other country of the vigorous stoloniferous grass *B. decumbens*, tolerant of poor acid soils with high Al saturation. In spite of serious doubts over the last few years about *B. decumbens* because of outbreaks of photosensitization in cattle grazing it, farmers have found this to be a relatively minor problem and are planting increasing areas of the grass. *B. decumbens* usually without an associate legume, is spreading like a "flood" over lowland tropical Latin America, and farmers and scientists will have to learn to live with it. There is no doubt that *B. decumbens* establishes readily over a wide range of conditions, including very acid Oxisols and Ultisols, and gives a marked increase in animal productivity over native pastures. CIAT (7) has shown that *B. decumbens* pastures at stocking rates of 1-2 steers/ha/yr will give liveweight gains of about 200 kg/ha/yr, but in the dry season weight losses can occur if stocking rates are too high. The problems associated with *B. decumbens* will be discussed later.

The legume-grass mixtures which have been sown widely in Brazil include *P. phaseoloides-C. pubescens-P. maximum* cv. Colonião (Amazonia), *M. atropurpureum-C. pubescens-P. maximum* cv. Colonião (Cerrado, etc. of São Paulo, Goias, Minas Gerais, southern half of Mato Grosso), and *M. atropurpureum* or *S. guianensis* with one among several grasses, especially *C. ciliaris* and *P. maximum* cv. Colonião (Northeast e.g. Maranhão, Ceara). *S. guianensis* has usually been included in most pasture mixtures, but has often failed after a few years so there is now less interest in this legume. Other legumes have been grown to some extent, such as *Glycine wightii* (R. Grah. ex Wight & Arn) Verdcourt and *Desmodium intortum* Mill. (Urb.) in better soils, and *Calopogonium mucunoides* Desv. and *Galactia striata* (Jacq.) Urb. over a range of soils. Definite interest is developing in Brazil in the tree legume *Leucaena leucocephala* (Lam.) De Wit which has grown well in limited areas of the Cerrado and other regions such as the Northeast.

A wide range of grasses have been tried, and confusion exists concerning which one should be planted in each of the many different ecological niches. However *B. decumbens* is the only grass seriously challenging the dominant position held by *P. maximum* cv. Colonião in Brazilian agriculture. Because of the spittle bug problem in *B. decumbens*, there is now interest in the more resistant *Brachiaria humidicola* (Rendle) Schweickt. *Melinis minutiflora* Beauv. is naturalized widely in the Minas Gerais hills and other areas such as Goias. Increased plantings of the various types of *C. ciliaris* are being made in the drier, less acid zones, including the Northeast. Other grasses being grown to some extent include Guianeazihno, Green Panic, Gatton Panic (cultivars of *P. maximum*), Nandi and Kazungula, (cultivars of *Setaria anceps* Stapf. ex Massey), *Digitaria decumbens* Stent., *Cynodon dactylon* (L.) Pers. and *Brachiaria radicans* Napper.

Allowing for its size, Brazil has done more pasture improvement than any other country in tropical America and will continue to dominate the scene. It needs more meat from its 100 million head of cattle to feed a rapidly increasing population of over 110 million people and for export. It is difficult to obtain definitive results on increased productivity of farms from pasture improvement. Farmers agree that after clearing, pasture sowing and fertilizing, their cattle production at least trebled, because stocking and calving rates were increased and slaughter age of steers significantly reduced. In the Cerrado, improved legume-grass pastures enabled a number of farmers to market Nellore steers of 450 kg liveweight at 2 to 2.5 years of age. Lack of persistence of the legume in a proportion of the pastures, due especially to overgrazing and soil deficiencies in some essential plant nutrients, has resulted in loss of pasture vigor and weed invasion with markedly reduced cattle production. Similar, but more severe problems have occurred with a number of legume-grass pastures sown in the Amazonian region after clearing heavy rainforest. Here loss of humus and nutrient leaching are at a fast rate. Unless adequate levels of essential nutrients like P, S, Mo and Zn are maintained in the soil the legume is lost, and once vigorous Amazonian pastures rapidly decline with invasion of woody regrowth, and spectacular decreases in cattle productivity. Poorly fertilized *B. decumbens* pastures, in spite of considerable initial vigor, also decline eventually because of P, S and other deficiencies.

Central America and Caribbean

Farmers and scientists in several Central American and Caribbean countries have been active in tropical pasture development.

In the Mexican Tropics, several national institutions (e.g. Instituto Nacional de Investigaciones Pecuarias (INIP), Palo Alto) have active pasture research programs. The Banco de Mexico and its staff of agronomists have promoted substantial pasture improvement projects among peasants and ranchers. These have been in sandy acid soil areas along the Southeast and Southwest coasts bordering the Gulf of Mexico and Pacific Ocean, respectively, and also in alkaline soil regions as in the Northeast around Tampico, the northwest of the State of Guerrero around Altamirano, and on the extensive marine limestone areas of the Yucatán Peninsula. **On the slightly acid** (about pH 5.5) **granitic soils** of the southern coasts 1-2 Brahman steers per ha can be fattened to slaughter weight at an age of about 30 months or less. Successful pastures on the slightly acid soils comprise the legumes *M. atropurpureum* and *C. pubescens* with *P. maximum* and fertilized with SSP (100-200 kg/ha) containing added Mo and Zn; in low lying wet areas close to the coast, *C. pubescens* is the best legume with grasses like *S. anceps* cv. Kazungula, *D. decumbens* and *C. dactylon*, the latter two often being too aggressive for the legume. The value of their widely spread indigenous *L. leucocephala* is now realized by Mexican scientists and farmers who are using it increasingly in both their acid and alkaline soils in combination with grasses like *D. decumbens*, *C. dactylon* and *P. maximum*. **On the alkaline soils** (pH 7.5) of the Yucatán Peninsula, clearing and burning the native scrub results in an almost pure stand of *L. leucocephala* which is then often interplanted with grasses like *C. ciliaris* and *P. maximum*; *M. atropurpureum* and *G. wightii* are other legumes used successfully on the Yucatán Peninsula. *L. leucocephala*, *M. atropurpureum* and *G. wigthii* have also proved to be the best pasture legumes for the alkaline, dry tropical areas of northwest Guerrero. **On the flat moist near neutral loams** around Villahermosa and Cárdenas, pastures of *C. dactylon* with *L. leucocephala* or *C. pubescens* and of *S. anceps* cv. Kazungula with *G. wightii* and *D. intortum* have been successful.

Among Caribbean countries, **Cuba** has one of the largest and most active research programs in pasture and animal production. Because of short-falls in domestic milk and meat production, the government gives considerable support to pasture and animal research. Many pasture areas are nearly neutral (pH 6.5) and the most promising legumes include *G. wightii*, *M. atropurpureum*, *C. pubescens* and *L. leucocephala*. *P. maximum* is favored for extensive use, and Cuba has one of the best ecotype collections of this species in Latin America. *D. decumbens*, usually under irrigation and with N fertilization, is used for intensive milk production.

CATTLE PRODUCTIVITY RELATIVE TO PASTURE FEEDING VALUE

In the various regions it is essential to know the main factors limiting animal production. It is now clear that improved tropical pastures need to supply the grazing animal with adequate digestible energy, protein and minerals for high levels of growth and reproduction. For most tropical American pasture development, nitrogenous fertilizers are too costly, and vigorous persistent legumes are the key to pasture and animal productivity. With legume-based pastures, adequate P, S, Ca, K, Mo, Zn and Cu, in particular are necessary and all these, except Mo, are essential for animal nutrition, as well as elements like Na, Co, and I. Poorly fertilized legume-grass pastures become deficient in legume and feed protein, and often have to be supplemented with licks containing several of the elements mentioned if a moderate level of animal production is to be maintained. It is not uncommon for animals to receive insufficient Na (22) from improved tropical pastures, and at times they do not provide the requisite Co and Cu (19, 31).

A well balanced tropical legume-grass pasture gives best results under continuous grazing, as young grass is selectively eaten early in the season and legumes mostly later in the season when grasses become fibrous and low in protein. Rigid rotational grazing reduces animal selectivity, overstresses and reduces the legume in the pasture, and so results in decreased liveweight gain per ha. There is a direct relationship between legume content of pasture and cattle liveweight gains (8). A relatively small proportion of legume (particularly if green) in dry season pastures maintains good levels of ruminal activity and intake of dry fibrous grass (20).

If improved tropical pastures supply all essential nutrient needs of animals as outlined, steers should reach slaughter weight (450-500 kg) at 30 months of age or younger. This needs to be the main aim of research and development in tropical America to ensure higher productivity on farms and raise the overall quality of the meat sold. The tough meat from 4-5 year old steers is not appetizing. The main objective with breeding cows is a high calving rate, and to achieve this they could probably spend a large proportion of their time on the poorest pastures, and only relatively short periods at critical stages (e.g. mating and calving) on improved legume-grass pastures, often a scarce resource. Growing steers, the highest revenue producers, need if possible to be given improved legume-grass pastures, all the year.

CURRENT PROBLEMS IN TROPICAL PASTURE IMPROVEMENT

Soil nutrient deficiencies

Correction of soil nutrient deficiencies affecting legume-grass growth is the most neglected aspect of pasture improvement in the Latin American Tropics. In these areas most acid soils are deficient in N, P, S, Ca, Mo and Zn and marginal in K and Cu, and sometimes in Mg. Often it is not realized that P and S are of equal importance in legume and grass growth. Also the almost universal deficiencies of Mo and Zn in many tropical Oxisols and Ultisols are overlooked. Heavy lime (and phosphate) applications aggravate Zn deficiency. In the Brazilian Cerrado and Amazonian areas it is difficult to find *C. pubescens* without the chlorosis associated with Zn deficiency. Both Mo and Zn are essential for legume growth, Mo being a vital metallic co-enzyme for N fixation in legumes (6). A number of progressive farmers using either SSP (9.6% P, 10% S, 20% Ca), TSP (without S) or rock phosphate on their legume-grass pastures often become dispirited when their legumes fail. It appears that legume failures are often due to unsuspected Mo and Zn deficiencies, although S deficiency could be significant where TSP or rock phosphates were applied.

Superphosphate with added minor elements, like Mo and Zn, are usually unavailable in Latin America. However, legume seed can be pelleted at planting with 175 g MoO_3/ha (= 100 g Mo/ha) or more to correct Mo deficiency (17) without inhibiting initial nodulation. It would be a big advance if

Zn could also be added to the pellet, but unlike MoO_3, ZnO is a very toxic to *Rhizobium. Perhaps use of finely divided Zn* metal would overcome the problem.

The world is richly endowed with phosphate resources (23) but transport, *treatment and application costs are a* problem in Latin America. Large phosphate deposits have been found in some countries, including Venezuela, Colombia, Perú and Brazil, but vigorous exploration is necessary to identify further deposits, especially in Brazil. For pastures, the cheaper rock phosphate (untreated or thermally modified) is usually satisfactory for legume-grass growth on acid P deficient Oxisols and Ultisols. Apart from price, it is also advantageous because of the high P fixation capacities of these soils (24). Rock phosphate, as well as TSP often need supplementation with S or SSP because of widespread S deficiency in Oxisols and *Ultisols. Subsoil S accumulation occurs in* some of these (e.g. Malaysian Rengam) and S deficiency in early growth disappears with deeper root penetration (24). It is economically important to determine the S status of the extensive regions of Oxisols and Ultisols considered for pasture improvement. The presence of subsoil S would mean that most P requirements could be supplied cheaply by rock phosphate. Forgetting cost, SSP is the best balanced P nutrient, but high fixation could be a problem in acid soils. However it appears that some legumes and grasses are able to utilize a relatively high proportion of the aluminum phosphate formed.

TSP is often preferred, because its high available P content reduces transport costs per unit of P. On this basis rock phosphate is costly to apply. This is a consideration in aerial phosphate applications in newly cleared areas (e.g. Amazon jungle) with stumps, partially burned logs, etc. There is no evidence that surface phosphate applications (ground or aerial methods) are less efficient than drilling phosphate into the soil.

Legume-grass vigor relative to soil nutrients

As discussed in the previous section, legume growth and that of the grass, are dependent on the supply of essential elements in the soil. Legumes are much more sensitive to nutrient deficiencies than grasses. It is unrealistic to consider improvement of pasture and cattle productivity in poor acid Oxisol and Ultisol regions without some inputs of any deficient essential elements. If farmers are not prepared to do this they should forget about pasture improvement and make best use of native pastures with low-cost mineral licks, etc.

Monitoring essential mineral elements in just mature legume leaves at peak pasture growth is the best index of available nutrients in the soil-pasture system, and indicates any deficiencies which need correction. For optimum growth and N *fixation, legume DM should contain 0.18-*0.20% P, 3.0% N, 0.14-0.18% S, 1.0% K, 1.0% Ca, 0.5% Mg, 1 ppm Mo, 35-40ppm Zn and 7-10 ppm Cu (4, 5). In tropical Latin America it is important to institute mineral monitoring of legume leaves in improved pastures to find minimal percentages of essential elements in DM necessary to maintain good growth and persistence. Fertilizing with major elements for maximum legume growth would probably be uneconomic. Scientists need to find economic fertilizer rates, which maintain good legume yield and persistence. This is essential if improved pastures are to expand and have real impact on cattle production. *Deficiencies of the minor elements Mo, Zn* and Cu must be corrected for legumes to persist, but their addition to the system is not costly if seed pelleting or pasture spraying with dilute solutions is used. About 0.5 kg/ha of a Mo compound and 5-8 kg/ha of zinc sulphate or copper sulphate (or both) are usually sufficient to correct any of these deficiencies for five years or more.

Johansen *et al.* (16) have found that the Mo requirement of legumes is influenced by a number of factors including site, soil pH and species. For example at one site, an initial application of 200 g/ha of Mo gave maximum growth of *G. wightii* for only two years, of *D. decumbens* for three years, and of *M. atropurpureum* for five years. At other sites, *M. atropurpureum* required much less Mo for maximum growth. The biggest responses to Mo were obtained at the sites with the lowest pH.

Reapplication of essential minor elements is best done with dilute sprays (ground or aerial) as indicated. Also there appears to be scope for maintenance applications of major elements as colloidal sprays during peak pasture growth. This could significantly reduce fertilizer costs.

A high level of grass production is primarily dependent on a vigorous legume component in the pasture, ideally up to 40% at the peak of the season. Legumes are unable to provide enough N for maximum grass growth, but this is not disadvantageous as protein rather than digestible energy is usually the main feed deficiency for animals in tropical pastures. Deficiencies of P, S or K often affect grass growth, but deficiencies of the essential minor elements Zn and Cu, do not appear to be so critical. In Brazilian Amazonia, three year old plantings of *P. maximum* cv. Colonião without phosphate fertilization, often become stunted with severe P deficiency (small plants, purple leaves) and chlorotic with S and N deficiencies. Any legumes planted with *P. maximum* cv. Colonião do not persist. Without vigorous competitive growth of *P. maximum* cv. Colonião, there is invasion of woody unpalatable species with pasture deterioration and significant loss of cattle productivity. *P. maximum* (and its ecotypes) is more sensitive to S deficiency than other grass species such as *B. decumbens* and *Andropogon gayanus* Kunth. With *B. decumbens* it is now common to see older unfertilized plantings, about six years old, in the Cerrado and Amazonia with deficiencies of N, P and S.

Selecting and breeding persistent adapted legumes

As stressed in previous sections, correction of soil nutrient deficiencies especially P, S, Ca, Mo and Zn is essential before it is possible to evaluate adaptation and persistence of any legume in grazed pastures of different regions. At some research centers, there is a tendency to keep legume introductions too long at the "museum plot stage" under periodic cutting. The sooner the range of legume plots are put under periodic grazing with a common associate grass (pregrazing quadrat cuts for DM yield, etc.), the sooner a few promising ecotypes can be selected and promoted to regular grazing trials. Scientists criticize this approach on the basis that species are differentially grazed, but is there a better system? Post grazing assessment is essential for proper evaluation. Very palatable legumes may not persist, but palatability is relative. For example, *Stylosanthes scabra* Vog. is often overlooked and considered undesirable because of coarseness and unpalatability at the peak of the season. However it is drought resistant and provides valuable green forage well eaten in the dry season. *S. scabra* is an important indigenous legume in drier regions, including the Cerrado and northeast Brazil, and bigger collections should be made and evaluated.

Persistent adapted legumes have not yet been commercialized for some important areas of tropical Latin American, such as the Colombian Llanos. In some areas, as already indicated, lack of persistence of current legume cultivars can be due to lack of attention to soil nutrient deficiencies. To be persistent, legumes (adequately fertilized) need to withstand grass competition, mismanagement (overgrazing, etc.) and periodic attack by a variety of insects and fungi, and have the ability to regenerate from crowns, rooted stolons and fallen seed. In spite of considerable research, only a few regions have persistent *Stylosanthes* cultivars. For example *Stylosanthes humilis* H.B.K. has been successful over a long-period with native *H. contortus*, especially in Central Queensland (26). Its place is being taken by *M. atropurpureum* and *Stylosanthes hamata* (L.) Taub., while *S. scabra* is proving valuable in hot monsoonal regions of the far north in Australia. *S. scabra* appears to have ability to compete with vigorous grasses like *P. maximum*, and is also resistant to the Australian biotypes of anthracnose *(Colletotrichum gloeosporioides)*. Failure of *S. guianensis* in Brazilian pastures could be due to inability to compete with the vigorous *P. maximum* cv. Colonião, as well to attack by anthracnose. CIAT's (7) research at Carimagua and Santander de Quilichao has clearly shown the anthracnose and insect problems (especially stemborer) which are making it difficult to select persistent *Stylosanthes* cultivars for the Latin American Tropics. These problems are a real challenge to scientists introducing, selecting and breeding *Stylosanthes* species.

Selecting and breeding legumes for tolerance to soil conditions (12) including low pH (low Ca, high Mn), low levels of P and other mineral nutrients, and waterlogging are very important aspects in development of legume cultivars for tropical Oxisols and Ultisols. Nodulation and growth at low pH (4.0) and low Ca are unaffected in some tropical legumes (e.g. *Macroptilium lathyroides* (L.) Urb. and *Lotononis bainesii* Baker) but severely inhibited in others (e.g. *Desmodium uncinatum* (Jacq.) D.C. and *G. wightii)* (1). In *M. atropurpureum* it was found possible to breed high yielding lines with a high degree of tolerance to high Al and Mn levels at pH as low as 4.2 (13, 15). This indicates scope for selecting and breeding vigorous lines from other legumes such as *C. pubescens*, and even *L. leucocephala*, for poor acid Oxisols and Ultisols. Ecotypes of several *Stylosanthes* species, *S. guianensis*, *S. scabra* and *S. capitata* are already well adapted to acid soils. When selecting and breeding legumes for acid soils, toxicities of both Al and Mn should be considered, as Mn toxicity could be more widespread than realized.

Some scientists consider that certain *Stylosanthes* species need almost no P and other nutrients because they occur naturally as scattered populations on very poor soils. However no legume can thrive in relatively dense legume-grass pastures without adequate inputs of essential nutrients. The protein levels in all legumes, including *Stylosanthes* species, is directly correlated to their P contents (4, 5). In several legumes, soluble Al in the substrate restricts uptake of P and Ca and reduces efficiency of translocation of P from roots to tops (2, 3). Legumes selected and bred for tolerance to low pH and excess Al could also possess increased efficiency in P utilization (13). Because of increasing fertilizer costs greater effort is required in selecting and breeding legume lines more efficient in utilization of all essential nutrients, including P.

Because of substantial areas of waterlogged soils in some regions, e.g. Pantanal of Brazil, legumes tolerant to these conditions are needed. Species with some flood tolerance include *M. lathyroides*, *Vigna luteola* (Jacq.) Benth., *Clitoria ternatea* L. and *C. mucunoides*. *Desmodium* is a widespread genus which appears to contain some flood tolerant species. One of the most promising water tolerant legumes observed is the northeastern Argentinian native *Phaseolus adenanthus*, first collected and studied at Corrientes by an INTA scientist. It is vigorous and stoloniferous and thrives in soils waterlogged for long periods.

Should legume seed be inoculated at planting?

In tropical Latin America there is a wide range of native legumes and a high and variable native *Rhizobium* population in the soil. Thus the question is often asked, why increase pasture establishment costs by inoculating seed? Where seed inoculation is used, the applied *Rhizobium* could soon be replaced by the abundant native *Rhizobium*. A lot of farmers have planted various legumes without inoculation and nodulation has been quite satisfactory. Why inoculate, is a very important question and needs an answer without delay in the Latin American

Tropics. Fortunately CIAT's (7) recent soundly based *Rhizobium* research has already shown in various legumes, marked differences in efficiency between inoculant strains, efficacy of rock phosphate pelleting (lime pelleting in *Macroptilium* sp.), and a distinct growth advantage from inoculation in the establishment phase of about two months. Inoculation could also be especially advantageous in legume-grass establishment following clearing of heavily forested areas like Amazonia, and with legumes not native to the area (e.g. *Leucaena* spp.) when grown in much of South America.

Which grass?

In improved pastures, grasses provide much of the digestible energy requirements but need to be compatible with legumes (unless N fertilizer used) to ensure a sufficiency of N and protein. The important grasses in the Latin American Tropics are African in origin. The main three at present are *P. maximum* and *B. decumbens*, with *C. ciliaris* for drier tropical areas. *M. minutiflora* and *Hyparrhenia rufa* (Nees) Stapf. are still planted and are naturalized over large areas, especially in Brazil. As discussed earlier, a number of other grasses are being tried, and of these *C. dactylon* ecotypes are probably the most important for particular conditions such as heavier soils. There is considerable scope for further selection in the main grasses, particularly *P. maximum*, (aided by the Tifton, Gainesville or African sexual types) for tolerance to lower P and S in acid soils and in *C. ciliaris* (aided by Bashaw's sexual type) for tolerance to low pH, Ca and P. It is of interest that *C. ciliaris* is unable to tolerate high soluble Mn levels, while *P. maximum* var. trichoglume has medium tolerance, and *Paspalum dilatatum* Poir. and *S. anceps* have high Mn tolerance (27).

Due to the considerable interest in *B. decumbens* and other *Brachiaria* species, there is an urgent need for scientists to compare the steer liveweight gain potentials of the *Brachiaria* species in suitable replicated trials, using *P. maximum* as a control. It may be possible to increase the variation for selection in *B. decumbens* through crosses with the sexual diploid, *Brachiaria ruziziensis* Germain & Evrard. The selection and promotion from germplasm banks of new and widely successful grass species will be difficult, although CIAT's (7) research with African *A. gayanus* selections has distinct promise.

Selection of grasses for waterlogged conditions is important for low-lying areas throughout the Tropics. Species with potential include *Echinochloa polystachya* (H.B.K.) Hitchc., *Brachiaria mutica* (Forsk.) Stapf., *Paspalum plicatulum* Michx., *S. anceps* and *Hemarthria altissima* (Poir.) Stapf. & Hubbard.

Tufted grasses are usually compatible with the main legumes, but strongly stoloniferous grasses often prevent the growth of associate legumes. The stoloniferous, aggressive *B. decumbens* widely grown without legumes now presents scientists with one of the most difficult pasture improvement problems in the Latin American Tropics. Eventually the *B. decumbens* pastures will become deficient in N, P, S, etc. and lose productivity, but cultivation and fertilization with introduction of legumes will only reinvigorate the *B. decumbens* and inhibit legume development. A stable pasture can be developed by first establishing spaced rows of *L. leucocephala*, and then planting the *B. decumbens* between. On the infertile Carimagua Oxisols, CIAT's (7) research has shown a promising compatibility between *B. decumbens* and the rather unpalatable *Desmodium ovalifolium* Vahl. (similar results were obtained on the poor coastal bris soils of east Malaysia). Vigorous ecotypes of *S. scabra* could also be compatible with *B. decumbens*.

In the last two to three years, as mentioned earlier, photosensitization in young cattle (up to about 15 months old) grazing *B. decumbens* was considered a major and serious problem, especially in Brazil.

Farmers now realize it is a management problem, and that they need alternate pastures, e.g. *P. maximum* for the younger cattle as soon as symptoms appear. It is significant that last season in Brazil *B. decumbens* was the grass seed in shortest supply, because of a resurgence in demand. Photosensitization of sheep and cattle (e.g. facial eczema) is from impaired liver function caused in New Zealand by a phytotoxin in *Pithomyces chartarum (Sporidesmium bakeri)*, a saprophytic fungus on the litter of *Lolium perenne* L. and other pasture species (9). In New Zealand it has now been shown that high Zn intakes in cattle and sheep protect against the phytotoxin and photosensitivity (30). The fungus is worldwide and occurs in Brazil and other Latin American countries, so it could be involved in photosensitization of cattle eating *B. decumbens.* Widespread Zn deficiency in poor tropical Oxisols and Ultisols, where much of the *B. decumbens* is grown, could be a predisposing factor (Zn is essential to maintenance of liver function). Other possible factors in young cattle include lower liver activity and partial development of the dark skin pigmentation of mature cattle. Also *B. decumbens* could contain a compound which has its greatest effect on young rapidly growing cattle.

Dry season problems and the role of legumes, including shrub types

If pastures have not been overgrazed in the wet season there is usually ample DM of variable to low quality available in the dry season. Some scientists and farmers advocate the costly procedure of cutting surplus summer forage for hay which is fed back in the dry season. As mentioned earlier, a small proportion of green legume in dry season pasture will maintain good ruminal activity and intake of fibrous grass, so that weight losses do not occur.

A number of the herbaceous legumes including *Stylosanthes* species, *M. atropurpureum* and *C. pubescens* are drought resistant and will produce some green leaf in the dry season. However the deep-rooting shrub and tree legumes, especially *L. leucocephala* (21), have the ability to produce significant amounts of valuable high protein leaf and shoots in the dry season for supplementing low quality fibrous grass. If *L. leucocephala* could be adapted to the acid Oxisols and Ultisols of the Latin American Tropics, it could if properly managed, obviate dry season feed problems in a number of regions. It is probably not practical to establish large areas of *L. leucocephala* in spaced rows with grasses planted between. However closely planted "protein banks" of *L. leucocephala* fenced and rotational grazed in conjunction with native or improved pasture (10 ha *L. leucocephala* per 100 ha of ordinary pasture) would not only improve summer liveweight gains but significantly increase dry season performance of cattle (11). The high and undesirable mimosine level in *L. leucocephala* cultivars will eventually be significantly reduced by crossing with other *Leucaena* species, including *Leucaena pulverulenta.* A study of the comparative effects of $CaCO_3$ on growth, nodulation and chemical composition of four *L. leucocephala* lines (3 bred) has indicated important factors (e.g. Ca and Al uptakes) involved in the adaptation of *L. leucocephala* to acid soils (14).

Low cost pasture development

Considerable research is needed in all important tropical regions to determine the cheapest methods of pasture establishment and maintenance, so that farmers will be encouraged to improve their pasture and cattle productivity. CIAT (7) is already devising low cost methods for the Colombian Llanos at Carimagua.

Wherever possible the existing grassland and savanna should not be destroyed during pasture improvement. This would not only lower costs but also provide cattle forage during the improvement phase. The Empresa de Pesquisa Agropecuaria de Minas Gerais, (EPAMIG of Belo Horizonte, Brazil) is studying the feeding value throughout the year of the low Cerrado scrub at Felixandia by means of oesophageal fistulated steers. It has been found that the Cerrado during a portion of the year provides good quality forage for grazing cattle. EPAMIG is considering methods of establishing suitable legumes (e.g. *S. scabra* and *M. atropurpureum)* with SSP, Mo and Zn in strips between the scrub using a simple but heavy drill. In the central Queensland *H. contortus* zone similar methods have been used but in some cases most of the larger Eucalyptus are poisoned individually with Tordon.

Seed production and supplies

There will be no significant increases in pasture improvement directly related to the development of new technology and promising new legume and grass cultivars in tropical Latin America, unless ample quantities of good quality seed of the cultivars are available commercially at reasonable prices. For some years Australia has been an important supplier of tropical pasture seed, but with the increasing tempo of tropical pasture improvement based on Australian cultivars, has not been able to produce the quantities of seed required. Fortunately CIAT (7) has been active for some years in the development of seed production methods for a number of new legume and grass cultivars. Also several commercial firms, notably in Brazil, have been producing increasing quantities of seed of important pasture cultivars. Scientists and governments need to give all the support possible to organizations producing relatively low cost pasture seed of good quality. Without this vital seed, the substantial increases in large scale pasture improvement needed for production of lower cost meat for lower income people will not be possible.

CONCLUSIONS

There have been enough successes with tropical pasture improvement in various countries to be confident that suitable low cost pasture technologies will be developed for the extensive areas of acid Oxisols and Ultisols with high Al saturation. The key is the selection and breeding of legumes adapted to soils of low pH, and which form stable persistent combinations with tufted grasses (e.g. *P. maximum)* under grazing which is sometimes too severe. The legumes need to be tolerant of relatively low nutrient levels, but are unable to form vigorous associations with grasses without inputs of essential elements including P, S, Ca, K, Mo, Zn and Cu. Grasses require much more study, and especially the problem of associating a legume with *B. decumbens.*

Soil nutrient deficiencies in the different acid soil regions need intensive study so that economic fertilizer practices can be devised. The dry season forage problem could be solved by the selection and breeding of drought resistant legumes able to produce green leaf in the dry season e.g. the valuable tree legume *L. leucocephala.* Low cost pasture improvement methods are required which cause minimal disturbance of the native forages. Without adequate commercial seed supplies of legume and grass cultivars, pasture improvement in tropical Latin America will be severely retarded.

LITERATURE CITED

1. Andrew, C.S. 1976. Effect of calcium, pH and nitrogen on the growth and chemical composition of some tropical and temperate pasture legumes. I. Nodulation and growth. Australian Journal of Agricultural Research 27:611-623.

2. ______, A.D. Johnson and R.L. Sandland. 1973. Effect of aluminum on the growth and chemical composition of some tropical and temperate pasture legumes. Australian Journal of Agricultural Research 24:325-339.

3. _____ and P.J. Vanden Berg. 1973. The influence of aluminum on phosphate sorption by whole plants and excised roots of some pasture legumes. Australian Journal of Agricultural Research 24:341-351.

4. _____ and M.F. Robins. 1969a. The effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. I. Growth and critical percentages of phosphorus. Australian Journal of Agricultural Research 20:664-674.

5. _____ and M.F. Robins. 1969b. The effect of phosphorus on the growth and chemical composition of some tropical pasture legumes. II. Nitrogen, calcium, magnesium, potassium, and sodium contents. Australian Journal of Agricultural Research 20:675-685.

6. Bergersen, F.J. 1971. Biochemistry of symbiotic nitrogen fixation in legumes. Annual Review of Plant Physiology 22:121-140.

7. Centro Internacional de Agricultura Tropical. 1978. Annual Report 1977. CIAT, Cali, Colombia. p. A-1-114.

8. Evans, T.R. 1970. Some factors affecting beef production of subtropical pastures in the coastal lowlands of South-East-Queensland. p. 803-807. *In* Proceedings XI International Grassland Congress, Surfers Paradise, Queensland, Australia.

9. Filmer, J.F. and A.T. Johns. 1960. Facial eczema; a brief resumé of 50 years' research. *In* Proceedings VIII International Grassland Congress, England.

10. Hutton, E.M. 1970. Tropical Pastures. Advances in Agronomy 22:1-73.

11. _____. 1974. Tropical pastures and beef production. World Animal Review 12:1-7.

12. _____. 1976. Selecting and breeding tropical pasture plants. Span 19:21-24.

13. _____ and L.B. Beall. 1977. Breeding of *Macroptilium atropurpureum*. Tropical Grasslands 11:15-31.

14. _____ and C.S. Andrew. 1978. Comparative effects of calcium carbonate on growth, nodulation, and chemical composition of four *Leucaena leucocephala* lines, *Macroptilium lathyroides* and *Lotononis bainesii*. Australian Journal of Experimental Agriculture and Animal Husbandry 18:81-88.

15. _____, W.T. Williams and C.S. Andrew. 1978. Differential tolerance to manganese in introduced and bred lines of *Macroptilium atropurpureum*. Australian Journal of Agricultural Research 29:67-69.

16. Johansen, C., P. C. Kerridge, P.E. Luck, B.G. Cook, K.F. Lowe and H. Ostrowski. 1977. The residual effect of molybdenum fertilizer on growth of tropical pasture legumes in a subtropical environment. Australian Journal of Experimental Agriculture and Animal Husbandry 17:961-968.

17. Kerridge, P.C., B.G. Cook and M.L. Everett. 1973. Application of molybdenum trioxide in the seed pellet for sub-tropical pasture legumes. Tropical Grasslands 7:229-232.

18. Mannetje 't, L. 1973. Beef production from pastures grown on granitic soil. Division of Tropical Agronomy, Commonwealth Scientific and Industrial Research Organization. Annual Report 1972-73. p. 19-20.

19. ______, A.S. Sidhu and M. Murugaiah. 1976. Cobalt deficiency in cattle in Johore. Liveweight changes and responses to treatments. Malaysian Agricultural Research and Development Institute Research Bulletin 4:90-98.

20. Minson, D.J. and R. Milford. 1967. The voluntary intake and digestibility of diets containing different proportions of legume and mature Pangola grass *(Digitaria decumbens)*. Australian Journal of Experimental Agriculture and Animal Husbandry 7:546-551.

21. National Academy of Sciences. 1977. *Leucaena:* Promising forage and tree crop for the tropics. U.S. National Academy of Sciences, Washington, D.C.

22. Playne, M.J. 1970. The sodium concentration in some tropical pasture species with reference to animal requirements. Australian Journal of Experimental Agriculture and Animal Husbandry 10:32-35.

23. Phillips, A.B. and J.R. Webb. 1971. Production, marketing, and use of phosphorus fertilizers. p.271-301. *In* Fertilizer technology and use. Soil Science Society of America Inc., Madison, Wisconsin, U.S.A.

24. Sanchez, P.A. 1976. Properties and management of soils in the tropics. Wiley, New York.

25. Shaw, N.H. and W.W. Bryan. 1976. Tropical pasture research—principles and methods. Bulletin Commonwealth Bureau of Pastures and Field Crops no. 51.

26. ______ and L. 't Mannetje. 1970. Studies on a speargrass pasture in Central coastal Queensland. The effect of fertilizer, stocking rate, and oversowing with *Stylosanthes humilis* on beef production and botanical composition. Tropical Grasslands 4:43-56.

27. Smith, E.W. 1978. Tolerance of sown pasture grasses to excess manganese. (In press).

28. Stobbs, T.H. 1975. Beef production from improved pastures in the tropics. World Review of Animal Production 11(2):57-65.

29. Teitzel, J.K., R.A. Abbott and W. Mellor. 1974. Beef cattle pastures in the wet tropics. Part I. Queensland Agricultural Journal 100:98-105.

30. Towers, N.K., B.L. Smith and D.E. Wright. 1975. Preventing facial eczema by using zinc. *In* Proceedings Ruakura Farmers' Conference.

31. Winter, W.H., B.D. Siebert and R.E. Kuchel. 1977. Cobalt and copper therapy of cattle grazing improved pastures in northern Cape York Peninsula. Australian Journal of Experimental Agriculture and Animal Husbandry 17:10-15.