THE VALUE OF ECOLOGICAL STUDIES IN ESTABLISHMENT AND MANAGEMENT OF SOWN TROPICAL PASTURES

L. R. HUMPHREYS* AND R. J. JONES**

ABSTRACT

Recent ecological studies of relevance to the establishment and management of tropical pastures are reviewed. The need for long term studies of field performance under grazing and for studies of plant adaptive mechanisms is discussed.

INTRODUCTION

Advances in the techniques of tropical pasture establishment and management depend upon a better understanding of the adaptive processes by which plants are ecologically successful and of the environmental factors which condition plant response. Exacting studies which monitor the environment and the behaviour of the sward in the field are needed, and these studies are most productive when supported by laboratory analyses and controlled environment experiments.

PASTURE ESTABLISHMENT

The agronomist seeks to provide a favourable environment in which seeds germinate, and seedlings emerge, grow and survive; a related objective is the suppression of unwanted species. Leslie (1969) listed four stages of vulnerability and their most common hazards as: physical loss of seed, loss of viability, emergence failure and seedling mortality.

There have been few critical field studies of tropical pasture establishment on any of these four stages reported since the 1968 Australian Grassland's Conference. For grass establishment, nothing has arisen to equal the interest of Leslie's (1965) discovery that the failure of grass sowings on a self-mulching cracking clay soil was mainly due to the layer of dry crumbs beneath the surface which impedes the emergence of germinated seedlings, an effect aggravated by the loss of penetrative capacity when light stimulates the appearance of the first leaf through the coleoptile. For these sub-coastal self-mulching soils emergence failure and seedling mortality as a result of moisture stress were identified as the major factors limiting establishment. Rickert (1970) subsequently showed that reducing moisture stress by a surface mulch enhanced establishment of *Panicum maximum* var. *trichoglume*.

In coastal areas Jones and Rees (1973) concluded that poor establishment was not a major limitation to the use of sown tropical pasture species on prepared seed beds. Jones (1975) emphasized the effect of soil fertility on the transitory response of the pasture to the variables of legume seeding rate, intensity of annual grass weed competition and intensity of first year defoliation. Slow and often poor establishment of *Glycine wightii* (Luck, Mears and Pulsford 1971) has been shown to be associated with a slow rate of nodulation and nitrogen fixation compared with Siratro; on fully established plants rate of growth and nitrogen accumulation were similar (Wilson 1972). Faster nodulation was achieved by the use of various carbon and nitrogen sources and Diatloff (1974) suggested the incorporation of N in the seed pellet. In the field, however, nitrogen applications have not proved successful (Whiteman 1972). This is another example of the dangers of seeking to solve problems in isolation without taking sufficient notice of interacting factors. A number of studies have now shown that the response of legumes to increasing superphosphate levels on fully

*Department of Agriculture, University of Queensland, St. Lucia 4067.
**C.S.I.R.O. Division of Tropical Agronomy, Cunningham Laboratory, St. Lucia 4067.

prepared seedbeds may be negative due to marked competition from sown grass and weeds in the presence of high levels of mineralised nitrogen (Jamieson 1969; Mears and Barkus 1970; Jones 1971).

Oversowing into unprepared seedbeds is a less reliable but inexpensive technique. The fire susceptibility of annual grasses in the seedling stage (Stocker and Sturtz 1966) is an excellent example of the ecological approach to reducing competition of the native species prior to sowing with *S. humilis*. The detailed studies of Dowling, Clements and McWilliam (1971) with temperate species indicate avenues which could be investigated with the tropical species. In particular the use of pelleting to improve water uptake of the surface sown seed warrants detailed study.

The occurrence of field salinity in the Queensland coastal lowlands (Evans 1967) and in the brigalow (Isbell 1962), and chloride toxicity from potassium chloride fertilizer (Hall 1971; R. M. Jones 1973) are limiting factors of establishment of some species.

MANAGEMENT OF SOWN PASTURES

One of the major aims of pasture management in the Australian context is the maintenance of an adequate legume component in the pasture, since both pasture yield (Jones, Davies and Waite 1967) and animal performance (Bryan 1970; Norman 1970) are positively related to legume component in the pasture.

a) Dynamics of S. humilis *pastures*

In the past decade there has been a greater appreciation of the positive effect of *S. humilis* on animal productivity, and a growing awareness of the instability of these pastures. In northern Australia legume contribution has been difficult to maintain both with natural grasses and with sown perennials such as *Cenchrus ciliaris* (Norman 1967) and Sabi grass (*Urochloa mosambicensis*) (Ive 1974), and annual grasses have displaced native perennial grasses under the high stocking rates employed (Ritson, Edye and Robinson 1971); erosion hazard may also increase. In southern Queensland, on the other hand, fertilized *S. humilis* has persisted well even under lenient cutting in the presence of sown perennial grasses (Shaw 1967) and also under grazing with native perennial grasses, chiefly *Heteropogon contortus* (Shaw and t' Mannetje 1970). The significant cool season rainfall component may favour the persistence of the native perennial grasses at the Rodd's Bay site.

Torssell (1973) has developed a technique for quantifying the stability of pasture components, and has proposed a model for studying the environmental factors determining annual grass/legume relationships. Different plant processes have different environmental optima, and the short-term dominance of particular plants arises from their greater resistance to particular stress conditions or their greater capacity to exploit favourable growth factors. Torssell segments the cycle of natural regeneration into the component phases of germination/establishment, growth period competition, and seed production, each of which constitutes a "filter" and affects the species balance at the commencement of the next phase. He suggests that at Katherine a short wetting period and rapid drying favours *S. humilis* germination/establishment, whilst subsequently good soil fertility and moisture supply favours *Digitaria ciliaris* during the growth period competition phase. One factor limiting the distribution of *S. humilis* to the lower latitudes is the adverse effect of low night temperature on the third filter, seed production; complete floral abortion occurs at about 12°C mean night temperature (Skerman and Humphreys 1975). The addition of a fourth 'filter' —maintenance of soil seed reserves, would add to the utility of this analysis; Cameron (1967) noted the effects of climatic conditions on the softening of *S. humilis* seed. Rapid genetic shift in response to stress (Burt, Williams and Compton 1973) is an aspect of its successful adaptation.

The simplistic explanation of fertility effects on the dynamics of *S. humilis* associations assumes that increasing supply of P and other nutrients increases legume N fixation (Shaw, Gates and Wilson 1966); nitrophilous grasses with the C_4 photosynthetic pathway and higher growth rates than *S. humilis* then compete for soil nitrogen more effectively (Vallis *et al.* 1967) and assume dominance. A cyclic increase of *S. humilis* is expected as soil N diminishes, although this has not been recorded. However, successful competition by grasses for applied P has occurred under conditions of low N supply (Norman 1965; Woods and Dance 1970).

In the Northern Territory, Eucalyptus woodland with tree densities of 54 ha^{-1} permitted more than 70% light penetration and Begg and Cunningham (1974) suggested competition for water and nutrients would be more important than that for light. At Lansdown, Williams and Gillard (1971) found that *S. humilis* frequency was negatively related to eucalypt density, whereas *Heteropogon contortus* was well adapted to the densely wooded sites. Gillard (1970) also showed that at the dry Kangaroo Hills site removal of trees was the dominant management influence on pasture productivity. No comparable data for more northern sites with a more reliable summer rainfall are available.

The shade intolerance of *S. humilis* (Sillar 1967) and its habit of basal branching leading to dominance over erect bunch grasses under frequent defoliation or heavy grazing (Ive and Fisher 1974) explain its initial success in situations of low fertility and heavy grazing pressure. However, the different behaviour of *S. humilis* and associated native grasses at Rodd's Bay, Townsville and Katherine are as yet unexplained. The short term studies of Norman (1966, 1970) highlighted the value of *S. humilis* as a cattle feed but the nature of these studies masked some real problems of annual grass and other weed invasion. More research is needed to identify adapted perennial grasses compatible with *S. humilis* under heavy grazing. These might act as a convenient sink for N accretion, provide better continuity of forage supply, and confer both erosion resistance and botanical stability. An alternative approach is to use perennial legumes capable of combining with sown perennial grasses; the *Stylosanthes* genus offers promise (Burt *et al.* 1974).

b) Persistence of perennial legumes

The low level of persistence of tropical legumes in coastal pastures in Queensland and northern New South Wales constitutes a most important research challenge.

Defoliation effects

Numerous studies (e.g. Jones 1967; Whiteman 1969; Bryan and Evans 1973; R. J. Jones 1973a, 1974a,b,c), illustrate the intolerance of *Macroptilium atropurpureum*, *Desmodium intortum*, *D. uncinatum* and other trailing legumes to severe defoliation and this is probably one of the main reasons for the poor persistence of these species in many grazed pastures. The response mechanisms are still not well understood but slow recovery after defoliation and the limited period over which a high leaf area is maintained when these legumes are frequently defoliated, are probably major factors. Where legume density is low the adverse effect of severe defoliation on stolon production (Jones 1974c) also results in lower legume yield and reduced ability to compete with associate grasses. In the short-term the regrowth yield of Siratro was more closely related to leaf area of the stubble than to previous cutting management designed to vary root size (Jones 1974c). In a longer term study, however, cutting management had a large residual effect on Siratro density and vigour, especially in the presence of a perennial grass (Jones 1974a). In the sub-tropics the competitive effect of the sown grasses is increased by their capacity for more growth at lower temperatures (Riveros 1970).

Although *Lotononis bainesii* has the ability to grow better than tropical grasses at low temperatures (t' Mannetje and Pritchard 1974), is tolerant of severe defoliation (Bryan, Sharpe and Haydock 1971) and low P supply (Blunt and Humphreys

1970) it has been unreliable in grazed pastures in coastal Queensland (Whiteman 1969; Bryan and Evans 1973).

In practice the grazier controls defoliation by manipulating stocking rate and by protecting paddocks from grazing. There is now sufficient evidence to indicate that heavy stocking rates—above 2 beasts ha^{-1} $annum^{-1}$—reduce the perennial twining tropical legumes, but the effect of resting for specific periods or of rotational grazing compared with continuous grazing has not been adequately examined. From the results of cutting experiments (Jones 1973a, 1974a) long rather than short rotations would be expected to benefit these legumes but the influence on animal productivity needs to be evaluated. With leucaena, preliminary results (Jones 1973b) indicate that substantial improvement in production occurred with even a simple two paddock system of grazing. In most comparisons of grazing systems the pasture data collected have been too meagre to provide an understanding of the differences or lack of differences recorded in animal production. Consequently, there are few leads to be pursued in any depth.

Plant nutrition

In some farm situations inadequate maintenance fertilizer dressings have caused decreasing legume content of pastures; this problem is aggravated in the current economic climate. In other papers legume fertilizer requirement and response are discussed; at this point attention is directed to a study by Hall (1974) of competitive and non-competitive relations in a *D. intortum/Setaria anceps* association. The approach of the de Wit (1960) replacement series study of plant interference was extended by considering both dry matter production and nutrient uptake. This confirmed that under conditions of low K supply *S. anceps* restricted the growth of *D. intortum* by competing for K. Satisfactory growth of *D. intortum* occurred in monoculture under relatively low K supply, indicating that extrapolation of the diagnosis of fertilizer needs from monoculture to mixed culture is hazardous. *S. anceps* and *D. intortum* were compatible under conditions of high K supply, due to the partial independence of each species with respect to nitrogen source. The possibility of manipulating grass-legume balance by suitable combinations of species and fertilizer regimes is worth pursuing in field studies.

The use of nitrogen fertilizer on tropical grass-legume pastures has usually resulted in a decline in the legume component (Jones 1967, 1970, 1971). In a mixture, tropical grasses compete more effectively than legumes for applied nitrogen (Vallis *et al.* 1967), and growth rates of legumes are less than those of tropical grasses (Ludlow and Wilson 1970). Differences in the growth rate of *S. anceps* and of *D. intortum* appear to be related more to differences in the relative photosynthetic capacity of the illuminated leaves rather than to differences in canopy structure (Heslehurst and Wilson 1971).

Other factors

In the absence of insect pests (e.g. Mears (1967)) obvious diseases, nutrient deficiencies or overgrazing, some species e.g. *L. bainesii* fail to persist (Whiteman 1969; Bryan and Evans 1973). Similarly on the cracking clays of the brigalow tropical legumes have failed to persist. Although high soil nitrogen leading to grass dominance, moisture stress, seasonal flooding and frosting have been considered there is a need for the dominant factors to be identified. Lucerne, which is the most persistent herbaceous legume in the brigalow, cannot be considered for permanent pastures because even under the recommended grazing and fertilizing regimes it rarely persists for more than four years (Cameron 1973). More success may be achieved with shrub legumes such as *Leucaena leucocephala.*

Plant persistence may occur through different pathways, whose relative importance requires assessment. Longevity of the original plant crowns, the generation of new rooted points on stolons or layered stems, or the cycle of seed production, soil seed reserves, and seedling emergence, growth and survival may predominate. Very little work has been done to measure the various reproductive strategies of pasture plants in grazed situations. In Siratro pastures where increasing stocking rates reduced animal gains, the Siratro density declined from 3.9 to 1.2 plants m^{-2} as stocking rate increased from 0.62 to 1.24 steers ha^{-1} (Bisset and Marlowe 1974). At Narayen E. Agishi (personal communication) found that seed reserves and seedling density were also negatively related to stocking rate. Few seedlings survived the season, a finding attributed more to shading effects than moisture stress in the favourable season in which measurements were made. At Samford, R. M. Jones (1974) found that although crown density of Siratro was similar over a range of stocking rates (1.1 to 3.0 heifers ha^{-1}), crown size and associated stolon development were reduced as stocking rate increased so that at the highest stocking rate plants had virtually no stolon development. Turnover of plants was low at low stocking rate and high at the high stocking rate, so that seedling regeneration was vital for maintenance of the legume under the high stocking rate. The lack of seed set on plants at this stocking rate would lead eventually to elimination of the legume. The importance of seedling regeneration for legume maintenance at all except the lightest stocking rate and the known ease with which Siratro seedlings establish and nodulate may partly explain its popularity as a pasture plant in a range of environments.

Since, as mentioned earlier, legumes are only intrinsically favoured under conditions of low nitrogen supply, legumes efficient in transferring nitrogen to associated grasses are penalised. This problem of growing tropical grasses with the efficient C_4 photosynthetic pathway with legumes possessing the less efficient C_3 pathway poses a real challenge. The use of low stocking rates which enables the twining legumes to overtop and display their leaves above the grass canopy (Riveros 1970) is one approach but this inevitably means a low utilization of the pasture. Using low growing grasses with inherently higher palatability than the legumes during their main growth phase is another approach which warrants investigation. Alternatively, the selection or breeding of legumes which transfer nitrogen only slowly to the associate grasses is a possibility (Vallis and Jones 1973). Finally, improvement in regrowth ability leading to higher legume yields and better persistence under frequent defoliation may be possible by selection and breeding, since a varietal effect of bud site number on rate of regrowth in *Stylosanthes guyanensis* was noted by Grof, Harding and Woolcock (1970) and substantial genotypic variation in defoliation tolerance of *Desmodium intortum* under glasshouse conditions was noted by Imrie (1971).

CONCLUSIONS

Present research needs may be summarized as follows:

1. Inadequate ecological data are available on changes in yield and botanical composition of grazed pastures. The importance of the time period in ecological studies implies that such studies will be long term and may require some central planning for continuation in spite of staff changes.
2. In association with the data collection referred to above is the need to understand the causes of botanical and productivity changes. The mechanisms which lead to success or failure of particular species, especially the legumes, need to be elucidated in order that the ecological studies may become predictive rather than merely descriptive.
3. In the Australian context pastures are grazed and not mown. This introduces not only other variables e.g. selectivity, treading, nutrient return, but also leads to considerably more variation than that experienced in mown plots. This should not continue to be a reason for retreating to isolated projects removed from the problem area. On the contrary, ways need to be sought to cope with the problem of variability within the grazed sward so that more meaningful results can be achieved in the grazed context.

4. The importance of stocking pressure and its influence on defoliation frequency and intensity must be recognized in all aspects of ecological work, since it affects the responses which may be obtained from other variables such as nutrient application, and the reproductive strategies of the species under study. Physiologists and plant breeders in related fields need to take this very important variable into account.

Empirical solutions have provided many of the advances in tropical pasture science. Further progress in this area must result from ecological studies leading to an understanding of the mechanisms by which plants are successful in the grazed pasture. Such studies should assist the interpretation of the results from grazing trials, enable prediction of species responses over a range of environment and management variables, and focus attention on species limitations which may be overcome by specific management strategies, further plant introduction or through plant breeding.

ACKNOWLEDGEMENT

We are indebted to R. M. Jones, C.S.I.R.O. Division of Tropical Agronomy, for valuable suggestions.

REFERENCES

Begg, J. E. and Cunningham, R. B. (1974)—*J. Aust. Inst. Agric. Sci.* **40**: 164.
Bisset, W. J., and Marlowe, G. W. C. (1974)—*Trop. Grassl.* **8**: 17.
Blunt, C. G., and Humphreys, L. R. (1970)—*Aust. J. Exp. Agric. Anim. Husb.* **10**: 431.
Bryan, W. W. (1970) *In* "Australian Grasslands," Ed. R. Milton Moore, A.N.U. Press, Canberra, p. 101.
Bryan, W. W., and Evans, T. R. (1973)—*Aust. J. Exp. Agric. Anim. Husb.* **13**: 516.
Bryan, W. W., Sharpe, J. P., and Haydock, K. P. (1971)—*Aust. J. Exp. Agric. Anim. Husb.* **11**: 29.
Burt, R. L., Edye, L. A., Williams, W. T., Gillard, P., Grof, B., Page, M., Shaw, N. H., Williams, R. J. and Wilson, G. P. M. (1974)—*Aust. J. Agric. Res.* **25**: 559.
Burt, R. L., Williams, W. T., and Compton, J. F. (1973)—*Aust. J. Agric. Res.* **24**: 703.
Cameron, D. F. (1967)—*Aust. J. Exp. Agric. Anim. Husb.* **7**: 237.
Cameron, D. G. (1973)—*J. Aust. Inst. Agric. Sci.* **39**: 98.
Diatloff, A. (1974)—*Aust. J. Agric. Res.* **25**: 577.
Dowling, P. M., Clements, R. J., and McWilliam, J. R. (1971)—*Aust. J. Agric. Res.* **22**: 61.
Evans, T. R. (1967)—*J. Aust. Inst. Agric. Sci.* **33**: 216.
Gillard, P. (1970)—Proc. 11th Int. Grassl. Cong., Surfers Paradise, Queensland: 807.
Grof, B., Harding, W. A. T., and Woolcock, R. F. (1970)—Proc. 11th Int. Grassl. Cong., Surfers Paradise, Queensland: 226.
Hall, R. L. (1971)—*J. Aust. Inst. Agric. Sci.* **37**: 249.
Hall, R. L. (1974)—*Aust. J. Agric. Res.* **25**: 749.
Heslehurst, M. R., and Wilson, G. L. (1971)—*Aust. J. Agric. Res.* **22**: 865.
Imrie, B. C. (1971)—*Aust. J. Exp. Agric. Anim. Husb.* **11**: 521.
Isbell, R. F. (1962)—Aust. C.S.I.R.O. Div. Soils, Soils Land Use Ser. 43.
Ive, J. R. (1974)—*Aust. J. Exp. Agric. Anim. Husb.* **14**: 558.
Ive, J. R., and Fisher, M. J. (1974)—*Aust. J. Exp. Agric. Anim. Husb.* **14**: 495.
Jamieson, G. I. (1969)—*Queensl. J. Agric. Anim. Sci.* **26**: 529.
Jones, R. J. (1967)—*Aust. J. Exp. Agric. Anim. Husb.* **7**: 157.
Jones, R. J. (1970)—*Trop. Grassl.* **4**: 97.
Jones, R. J. (1971)—Ph.D Thesis, Univ. N. Engl., Armidale, N.S.W.
Jones, R. J. (1973a)—*Aust. J. Exp. Agric. Anim. Husb.* **13**: 171.

JONES, R. J. (1973b)—Aust. C.S.I.R.O. Div. Trop. Agron. Ann. Rep. (1972-73), p. 15.
JONES, R. J. (1974a)—*Aust. J. Exp. Agric. Anim. Husb.* **14**: 334.
JONES, R. J. (1974b)—*Aust. J. Exp. Agric. Anim. Husb.* **14**: 343.
JONES, R. J. (1974c)—*Proc. Aust. Soc. Anim. Prod.* **10**: 340.
JONES, R. J., DAVIES, J. G., and WAITE, R. B. (1967)—*Aust. J. Exp. Agric. Anim. Husb.* **7**: 57.
JONES, R. M. (1973)—*Trop. Grassl.* **7**: 29.
JONES, R. M. (1974)—Aust. C.S.I.R.O. Div. Trop. Agron. Ann. Rep. (1973-74), p. 18.
JONES, R. M. (1975)—*Aust. J. Exp. Agric. Anim. Husb.* **15** : 54.
JONES, R. M. and REES, M. C. (1973)—*Trop. Grassl.* **7**: 219.
LESLIE, J. K. (1965)—*Queensl. J. Agric. Anim. Sci.* **22**: 17.
LESLIE, J. K. (1969)—Proc. Aust. Grassl. Conf., Perth, 1968, **2**: 57.
LUCK, P. E., MEARS, P. T., and PULSFORD, J. S. (1971)—*Trop. Grassl.* **5**: 81.
LUDLOW, M. M., and WILSON, G. L. (1970)—*Aust. J. Agric. Res.* **21**: 183.
t'MANNETJE, L., and PRITCHARD, A. J. (1974)—*Aust. J. Exp. Agric. Anim. Husb.* **14**: 173.
MEARS, P. T. (1967)—*Trop. Grassl.* **1**: 98.
MEARS, P. T., and BARKUS, B. (1970)—*Aust. J. Exp. Agric. Anim. Husb.* **10**: 415.
NORMAN, M. J. T. (1965)—*Aust. J. Exp. Agric. Anim. Husb.* **5**: 120.
NORMAN, M. J. T. (1966)—Aust. C.S.I.R.O. Div. Land Res. Reg. Surv. Tech. Pap. 28.
NORMAN, M. J. T. (1967)—*J. Aust. Inst. Agric. Sci.* **33**: 14.
NORMAN, M. J. T. (1970)—Proc. 11th Int. Grassl. Cong., Surfers Paradise, Queensland 829.
RICKERT, K. G. (1970)—*Trop. Grassl.* **6**: 71.
RITSON, J. B., EDYE, L. A., and ROBINSON, P. J. (1971)—*Aust. J. Agric. Res.* **22**: 993.
RIVEROS, F. (1970)—Ph.D Thesis, Univ. Qd.
SHAW, N. H. (1967)—Aust. C.S.I.R.O. Div. Trop. Past. Ann. Rep. (1966-67), p. 14.
SHAW, N. H., GATES, C. T., and WILSON, J. R. (1966)—*Aust. J. Exp. Agric. Anim. Husb.* **6**: 150.
SHAW, N. H., and t'MANNETJE, L. (1970)—*Trop. Grassl.* **4**: 43.
SILLAR, D. I. (1967)—*Queensl. J. Agric. Anim. Sci.* **24**: 237.
SKERMAN, R. H., and HUMPHREYS, L. R. (1975)—*Aust. J. Exp. Agric. Anim. Husb.* **15**: 74.
STOCKER, G. C., and STURTZ, J. D. (1966)—*Aust. J. Exp. Agric. Anim. Husb.* **6**: 277.
TORSELL, B. W. R. (1973)—*J. Appl. Ecol.* **10**: 463.
VALLIS, I., HAYDOCK, K. P., ROSS, P. J., and HENZELL, E. F. (1967)—*Aust. J. Agric. Res.* **18**: 865.
VALLIS, I., and JONES, R. J. (1973)—*Soil Biol. Biochem.* **5**: 391.
WHITEMAN, P. C. (1969)—*Aust. J. Exp. Agric. Anim. Husb.* **9**: 287.
WHITEMAN, P. C. (1972)—*Trop. Grassl.* **6**: 11.
WILLIAMS, W. T., and GILLARD, P. (1971)—*Aust. J. Agric. Res.* **22**: 245.
WILSON, J. R. (1972)—*Aust. J. Agric. Res.* **23**: 1.
de WIT, C. T. (1960)—*Versl. Landbowkd. Onderz* No. 66 (*8*), 1.
WOODS, L. E., and DANCE, R. A. (1970)—*J. Aust. Inst. Agric. Sci.* **36**: 45.