EVALUATION OF FERTILIZER REQUIREMENTS OF TROPICAL LEGUME BASED PASTURES

C. S. ANDREW* AND R. C. BRUCE‡

ABSTRACT

This paper reviews current knowledge on the fertiliser requirements of tropical legume based pastures. Emphasis is on fertilisers for maintenance purposes. The assessment of requirement is discussed with regard to soil and plant chemistry, animal factors, and field experiments. The concept of crop logging or monitoring is developed. Discussion follows on the soil-plant relationships, plant-animal relations, and the combination of soil, plant and animal.

INTRODUCTION

In northern Australia the use of fertiliser on pastures, especially superphosphate, has been low, except for the areas with favourable rainfall on the wet tropical coast and Atherton Tableland, in south-east Queensland, and north-east New South Wales. Figure 1 shows the relative usage of superphosphate by zones in Queensland and the Northern Territory. The total amount of superphosphate used on pastures in Queensland and the Northern Territory represents only 1.4% of the total superphosphate usage on all Australian pastures (Molnar 1974), despite the fact that an area of 112 million ha is available in the tropics compared with 60 million ha in temperate Australia (Davies and Eyles 1968).

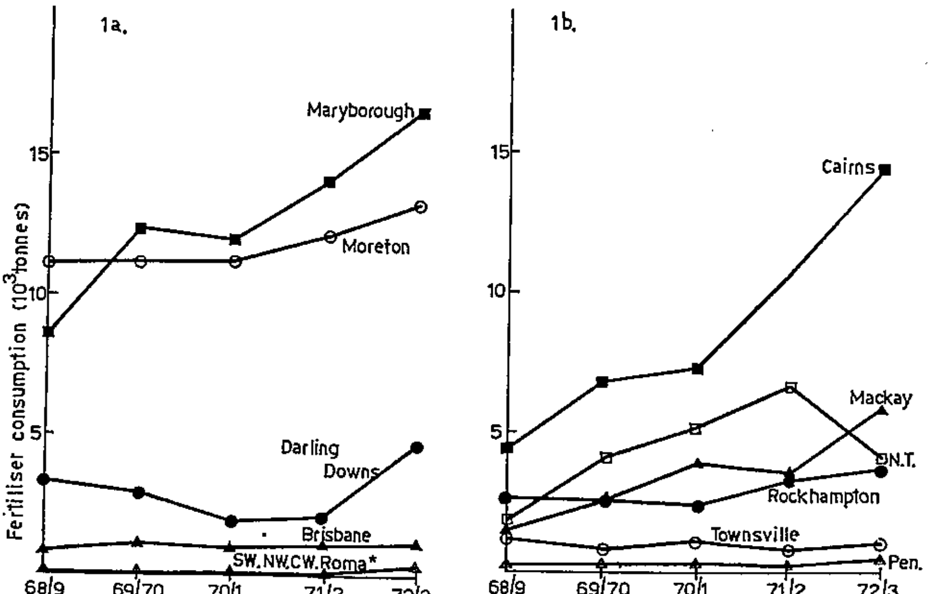

FIGURE 1

Fertiliser consumption (all forms) on pastures in the principal statistical divisions of Queensland and Northern Territory (Australian Bureau of Statistics).

1a. South of the Tropic and including N. West districts.
1b. North of the Tropic.
* S.W. = South-West, N.W. =North-West, C.W. = Central-West.

*Division of Tropical Agronomy, C.S.I.R.O., St. Lucia, Brisbane.
‡Department of Primary Industries, Indooroopilly, Brisbane.

The soil-plant-animal relationship can only be developed on a time basis and implies emphasis on the maintenance aspect of fertiliser usage. It would appear that the reticence in using superphosphate is largely due to economic reasons.

The major questions in relation to economic usage of fertiliser are how much to use at any one application, how frequently should fertiliser be applied and what are the expected financial gains from its use. Can technical recommendations be made for these purposes?

Because the role of fertilizers for pasture establishment is fairly well understood in most regions of northern Australia the emphasis in this paper is on fertilizers for pasture maintenance. A comprehensive review of published work will not be attempted. The approach will be to highlight gaps in our knowledge and to suggest ways of closing these gaps.

PHILOSOPHIES

Production potential

Research should initially provide information to cover the full resource and biological potential, commensurate with maximum use of the physical environment i.e. maximum production of plant and animal products. However, maximum plant production may not necessarily coincide with maximum animal production and neither of these may result in maximum economic return per unit area.

In rate of nutrient application experiments it is necessary for the researcher to decide what his objectives are, e.g. dry matter, recoverable nutrient, protein, or animal products in their various forms. The principal nutrients that have greater effects on protein production than on dry matter production of legumes are sulphur (Jones *et al.* 1971), phosphorus (Andrew and Robins 1969b; Gates *et al.* 1966), and molybdenum.

The full effect of nutrients such as these can only be achieved over a sufficiently long time span to allow full expression on dry matter production of legumes, the amount of nitrogen produced, the use of the nitrogen by the grass and the animal, the balance of legume to grass, and the overall animal production. Little is known about the production requirements of nutrients by animals in relation to plant requirements, e.g. the phosphorus critical percentage in *Stylosanthes humilis* for maximum dry matter is 0.17% P (Jones 1968; Andrew and Robins 1969a) but is this sufficient to achieve optimum animal phosphorus nutrition? Many overseas phosphorus standards for animal nutrition are considerably in excess of the above percentage. The accepted A.R.C. standard is approximately 0.35% P and that of North Carolina is approximately 0.25% P. The integration of soil applied phosphorus and supplemental phosphorus direct to the animal may be the answer.

Economic potential

Graziers are well aware of the factors that determine the input costs of added fertilizer e.g. basic fertilizer, transport, storage, spreading, pasture and property facilities and management. Questions that are posed are the quantity and form of fertilizer and the frequency of addition *in relation to animal production*. In addition to the limited accrued data on soil-plant-animal relationships, can researchers qualify the plant-animal relationships so that much of the current data on plant production from fertilizer experiments could be transposed into projected animal production units?

ASSESSMENTS OF MAINTENANCE FERTILIZER REQUIREMENTS

Soil chemistry

The only published data for tropical pastures are for pasture establishment (White and Haydock 1968; Bruce and Bruce 1972) and calibrations could well be different with established plants whose initial demands for nutrients have been met and whose extensive root systems exploit a large volume of soil. In addition, calibrations need to be obtained between soil tests and the response of grass-legume pasture mixtures, as a plant's nutrient requirements may be different when grown in association with other species (Hall 1974). For example at Rodds Bay, Townsville stylo growing with spear grass on a soil with exchangeable K of 0.22 m-equiv per 100 g contained 0.34%K and responded strongly to applied potassium. The result was in accord with plant diagnostic standards but not with soil standards.

As the nutrient status of a soil is altered by fertilizer additions calibrations need to be checked in case fertilizer reaction products cause the extractant to over estimate nutrient availability. For example it is possible that the ratio of acid extractable P to bicarbonate extractable P could increase with fertilizer usage. It is unlikely that a single soil test calibration will apply to a range of soils with different chemical properties. Colwell and Donnelly (1971) have shown that for some N.S.W. soils P test values are affected by variation in soil composition, particularly with respect to Fe, Al, Mg, and Ca.

The spatial variability in soil chemical composition is high in fertilized, grazed pastures. Standley (1975) has found coefficients of variation ranging from 5 to 71% for P and from 5 to 45% for K in north Queensland pastures. Intensive sampling is required under such conditions (Vallis 1973). Standardization on depth of sampling (0-10 cm for pastures) is an obvious requirement but other less obvious ones are sampling soils at a particular time of year (consider temperatures, plant growth and nutrient uptake) at a certain moisture content, and as long as possible after the last fertilizer application (at least 6 months and preferably 12 months).

Plant chemistry

The basis on which plant chemical composition is used for nutrient assessment is well documented (Macy 1936; Ulrich 1952 and others). The majority of initial tropical pasture research accomplished in this field has covered the principal tropical legumes and grasses (Andrew and Robins 1969a; Andrew and Robins 1969c; Andrew and Robins 1971; Smith in press; White and Haydock 1970; and others). A new phase (age × plant part) has been entered (Smith 1975; Bruce 1974; Henzell and Oxenham 1973; Johansen unpublished data). Critical plant nutrient concentrations (plant indices) have not been fully verified for pastures under conditions of full grazing. Neither is it known whether the indices so determined correspond with maximum animal production.

Animal diagnosis

Under conditions of grazing and particularly extensive grazing, the sufficiency of nutrients in the system may be judged by chemical analysis of certain animal tissue and blood. However many problems exist and reliable indices have been developed for only a few nutrients and these are primarily concerned with direct mineral nutrition. If one argues that the soil-plant-animal relationship is largely dominated by nitrogen and its association effects on plants, e.g. plant morphology and energy, the detection or usefulness of indices associated with nitrogen are not well developed for animal purposes. The challenge exists and it is hoped that researchers will continue to probe this avenue as a means of diagnosis.

Fertilizer maintenance experiments

Three forms of experimentation are available. Firstly the full soil-plant-animal grazing experiment using rates of nutrient addition as treatments. Animal results accruing from such experiments are of local use but may be extended to larger areas depending on survey results in relation to soil type and environmental factors. Basic information obtained from the above experiments especially that relating animal performance to soil, plant, or animal indices is extremely valuable in verification of indices derived under more controlled conditions and modification of them if necessary (see Table 1). Extended use of these indices to other similar and dissimilar sites is then possible.

TABLE 1

Animal production from five sites in relation to fertilizer usage and available soil phosphate

Location and Fertilizer Treatment (kg P $ha^{-1}yr^{-1}$)	Duration of Expt. (years)	Animal L.W.G. (kg $ha^{-1}yr^{-1}$)	Soil P+ (ppm)
1. Rodds Bay			
control	9	63	5 } (8th year)
S. humilis+10 P		136	10 } (8th year)
S. humilis + 20 P		123	40 } (8th year)
2. Narayen			
control	5	34	8–10 (initial)
M. atropurpureum + *C. ciliaris* + 25 P		135	
3. Townsville (Kangaroo Hills)			
control	5	23	6 (initial)
Timber removed + *S. humilis* + 10 P		173	
4 Beerwah			
control (*A. affinis*)	8	80	3 } (7th year)‡
sown pasture + 10 P		176	19 } (7th year)‡
sown pasture + 20 P		268	20 } (7th year)‡
5. Parada (irrigated)			
C. pubescens + *B. mutica* + 20 P	3	920	35–42 (initial)
C. pubescens + *B. mutica* + 40 P		860	

1–4 C.S.I.R.O. Division of Tropical Agronomy Reports.
5 D.P.I. Report (Evans, Ebersohn and Pulsford)
+ N/100 H_2SO_4 extraction.
‡mean over four soil types.

The second form is to superimpose nutrient rate of application experiments on an area being grazed and then to assess the sufficiency of the treatment by comparing the dry matter or nitrogen production from the untreated area with that from the superimposed treatments, using a cutting technique. This form is only possible in a rotationally grazed system or where small representative areas of the pastures are enclosed for a period sufficiently long to allow assessment of response. However in addition it allows verification of indices particularly in relation to soil-plant relationships.

The third form is to take soil from the pasture and to do nutrient response experiments in a glasshouse using standard pot culture techniques. Results from such experiments do not correlate well with field results.

Application

The ideal application of the above techniques lies within the concept of crop logging or monitoring. One of the misconceptions with regard to the use of soil and plant diagnostic indices is that it is thought that they can be used universally for any period within the year and across soil types and for all plant species. It must be stressed that the highest degree of accuracy of prediction is achieved by full standardisation of the chosen technique (Andrew 1965, 1968). Secondly, in relation to seasonal growth of pasture species it is only necessary to monitor the system once or twice per year, particularly in relation to a possible yearly application of fertilizer. In the case of soil indices the desirable periods would be at the commencement or the close of the growing season or preferably in accordance with the sampling time used in the soil-plant correlation studies.

In the case of plant indices, sampling procedures and choice of samples should be in accordance with the conditions used in the soil-plant studies from which the indices were developed (age, plant part, soil moisture, temperature, light, freedom from disease and insect damage). In order to achieve these conditions under continuous grazing it may be necessary to cage the plants temporarily or select specific portions of the plant. Rotational grazing largely overcomes this limitation.

An example of the soil-pasture monitoring system is that used by Mr. Teitzel and Dr. Standley on pastures in Queensland's wet tropics. They have chosen 30 ppm acid extractable phosphorus (N/100 H_2SO_4) and 0.30 m-equiv exchangeable K per 100 g as the base lines. The yearly application of superphosphate and potash are thus geared to the analytical results. Similarly plant analysis has been used by Andrew on an experimental basis at Samford and Beerwah. Other studies are in progress.

While such techniques are final targets or goals, the provisional soil and plant indices require further verification and checking by plant-response. It is in this discipline that researchers must develop techniques suitable for use in the presence of the grazing animal e.g. the cage technique (Andrew unpublished data). The research stage beyond this point is the study of the full soil-plant-animal relationship (future research).

Quantitative aspects

The efficiency of a superphosphate application relative to the full biological potential decreases with time and tends to reach a low plateau. Figure 2 presents results for *S. humilis* in a deep granitic sand in north Queensland.

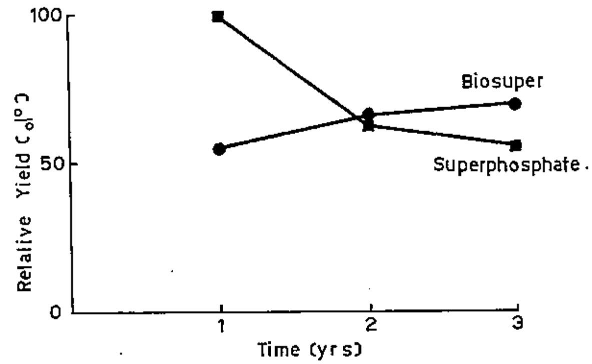

FIGURE 2

The effect of initial applications of superphosphate and biosuper (48 kg Pha^{-1}) on the relative yield of S. *humilis* over a 3 year period (Jones, pers. comm.).

In situations where annual additions of superphosphate are questioned on economic grounds, the problem is to determine the effect of an omission on both plant dry matter and more importantly on animal production. Information of this type is currently not available for the tropics. There is evidence accumulating to show that with the use of annual applications of superphosphate and moderate grazing pressure some of the existing improved pastures in northern Australia are botanically unstable (Ritson *et al.* 1971; Winks 1973). This may be looked upon as an adverse effect of superphosphate on the existing pasture species and systems used. However it may also be speculated that the native grasses in dominant use are not capable of coping with the modified system and are sub-optimal with reference to full biological physical potential. Secondly, cases have been reported in which the initial application of superphosphate to *Stylosanthes*-grass pastures, especially in new sowings, has resulted in relatively greater response in the grass than in the legume, with resultant poor establishment of the *Stylosanthes*. Interactions of available nutrients, especially nitrogen and phosphorus play an important role in this regard. Further research is required into the compatability of legumes and grasses in accord with management particularly the input of fertilizer and the output of animal product.

In all tropical grazed pastures used for maintenance type fertilizer experiments the chief problem has been lack of uniformity of legume-grass balance particularly as the experiment progresses. This problem is far greater than that associated with fertility spots and soil differences. However it highlights the necessity to parallel fertility research with that of many other agrostological disciplines.

The relative effectiveness of soil application of molybdenum has some similarities with that of superphosphate. Figure 3 based on data of Johansen, Kerridge and Luck for *Desmodium intortum* grown in the Cooroy district (Xanthozem soil) shows the quantitative aspects of Mo usage.

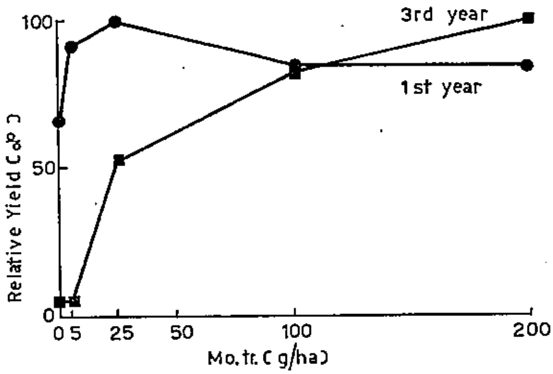

FIGURE 3

The effect of initial applications of molybdenum on the relative yield of *D. intortum* over a three year period.

FUTURE RESEARCH

1. Continued and strengthened research into the soil-plant relationship, particularly in the presence of the grazing animal, making full use of soil and plant diagnosis and the crop logging concept. This should be followed along two lines. Firstly in an accumulative system i.e. commencing from virgin situation and continuing year by year until no further growth responses occur. Secondly in a depletion system i.e. commencing from a fully sufficient system to ascertain the effect of omission of fertilizer year by year. Within each of these bi and tri-ennial effects could be investigated.
2. Development of techniques for and enlarged input of money into, the study of soil-plant-animal relationships. Experiments involving two or three rates of fertilizer application provide a limited amount of verification but in the short term they do not provide full data sufficient for evaluation of soil-plant-animal indices. C.S.I.R.O. experiments commenced at Beerwah and Narayen using animals in conjunction with soil and plant criteria and following omission or modification of fertilizer usage, represent a developing approach to this problem.
3. Increased emphasis on research into plant-animal relationships on a quantitative basis. Improved knowledge in this discipline would allow some integration of the soil-plant relationship with that of the plant-animal relationship to the point where soil-plant-animal relationship could be compounded.

REFERENCES

Andrew, C. S. (1965)—*J. Aust. Inst. Agric. Sci.* **31**: 3-10.
Andrew, C. S. (1968)—*J. Aust. Inst. Agric. Sci.* **34**: 154-62.
Andrew, C. S. and Robins, M. F. (1969a)—*Aust. J. Agric. Res.* **20**: 665-74.
Andrew, C. S. and Robins, M. F. (1969b)—*Aust. J. Agric. Res.* **20**: 675-85.
Andrew, C. S. and Robins, M. F. (1969c)—*Aust. J. Agric. Res.* **20**: 1009-21.
Andrew, C. S. and Robins, M. F. (1971)—*Aust. J. Agric. Res.* **22**: 693-706.

BRUCE, R. C. (1974)—*Trop. Grassl.* **8**: 137-44.
BRUCE, R. C. and BRUCE, I. J. (1972)—*Aust. J. Exp. Agric. Anim. Husb.* **12**: 188-94.
COLWELL, J. D., and DONNELLY, J. D. (1971)—*Aust. J. Soil Res.* **9**: 43-54.
DAVIES, J. G. and EYLES, A. G. (1968)—*In* "Pasture improvement in Australia" (Ed. B. Wilson) K. G. Murray, Sydney.
GATES, C. T. WILSON, J. R., and SHAW, N. H. (1966)—*Aust. J. Exp. Agric. Anim. Husb.* **6**: 266-76.
HALL, R. L. (1974)—*Aust. J. Agric. Res.* **25**: 749-56.
HENZELL, E. F. and OXENHAM, D. J. (1973)—*Commun. Soil Sci. Pl. Anal.* **4**: 155-61.
JONES, R. K. (1968)—*Aust. J. Exp. Agric. Anim. Husb.* **8**: 521-7.
JONES, R. K., ROBINSON, P. J., HAYDOCK, K. P., and MEGARRITY, R. G. (1971)—*Aust. J. Agric. Res.* **22**: 885-94.
MACY, P. (1936)—*Pl. Physiol., Lancaster.* **11**: 749-64.
MOLNAR, I. (1974)—"A Manual of Australian Agriculture", Third Edition. (W. Heinemann Australia Pty Ltd., Melbourne).
RITSON, J. B., EDYE, L. A., and ROBINSON, P. J. (1971)—*Aust. J. Agric. Res.* **22**: 993-1007.
SMITH, F. W. (in press)—*Aust. J. Exp. Agric. Anim. Husb.*
STANDLEY (1975)—Proc. Aust. Con. Trop. Pasture, 5-66.
ULRICH, A. (1952)—*Ann. Rev. Pl. Physiol.* **3**: 207-28.
VALLIS, I. (1973)—*Commun. Soil Sci. Pl. Anal.* **4**: 163-70.
WHITE, R. E., and HAYDOCK, K. P. (1968)—*Aust. J. Exp. Agric. Anim. Husb.* **8**: 561-8.
WHITE, R. E., and HAYDOCK, K. P. (1970)—*Aust. J. Exp. Agric. Anim. Husb.* **10**: 426-30.
WINKS, L. (1973)—*Trop. Grassl.* **7**: 201-8.