list of plants documented as the cause of photosensitization in domestic animals is a different species, *Brachiaria brizantha* (Clarke and Clarke 1975). In the trials reported here, with *Brachiaria decumbens*, photosensitization and jaundice were the main features. However, in Nigeria, these symptoms have not been reported in cattle. Although *Brachiaria decumbens* has been demonstrated to be the most promising grass in pure swards in northern Nigeria (Foster and Mundy 1961), further investigation would be required of its effects on cattle, sheep and goats.

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PROCEEDINGS

FERTILIZERS FOR PASTURES—THEIR USE OR ABUSE

Canungra Field Meeting, May 10, 1985

The first field day of the Tropical Grasslands Society in 1985 was held on 10th May on the property of Mr. and Mrs. H. G. Benstead at Canungra. Talks were presented on the theme "Fertilizers for Pastures—their use or abuse" by various speakers, and then followed an inspection of irrigated river flats which had ryegrass/clover pastures oversown into kikuyu. These pastures had been treated with Roundup while one area was also deep ripped to alleviate soil compaction. Another area had been fertilized with nitrogen and sulphur, while another had received only nitrogen to demonstrate the sulphur problem on the farm.

INTRODUCTION—NEED FOR NUTRIENTS

B. WALKER

Department of Primary Industries, Brisbane

Twenty-five years or more of work has gone into fertilizer research for tropical pastures by CSIRO, DPI, Queensland University and commercial firms. By this time, we should have solved many of the problems, but unfortunately there is still a lot unknown and a lot of problems remain to be solved.

What has highlighted the concern about fertilizer use is that, of the 3.7 million hectares of improved pasture in Queensland (of which 1 million ha are legume/grass pastures), only 150 000 ha of this are being fertilized. This represents less than 10% of the total acreage.

There are a number of reasons why fertilizers are not being used, and here I am talking about phosphorus, sulphur and potassium rather than nitrogen. 1) The effects of lack of fertilization are not obvious straight away, and it may take several years before the effects show up. 2) Many problems are more complicated than was first thought; all are not simple deficiencies which can be solved by just applying the deficient nutrient. There are interactions between nutrients which are not fully understood. 3) Most of the early work was done on a statewide basis, but when you come down to it, many problems are specific to local areas, for example the sulphur problem in the Beaudesert area and the possible selenium toxicity on the property we are presently visiting. 4) There are now different species of plants being used in the pastures sown today, and these can have different nutrient requirements to those species used in the original fertilizer research. For example, the shrubby stylos can be grown without use of phosphorus, but do we still need to apply phosphorus for the animal? Temperate pasture species may have different nutrient requirements compared to tropicals. 5) The increased use of nitrogen on grasses increases the demands on other elements.

The talks today are aimed at highlighting these and other problems. One aspect which will be addressed is that of *Soil Testing*. In southern Australia there has been a large amount of work assessing the value of soil tests and this work has been fairly inconclusive. Soil tests and the need to apply nutrients are not always well correlated. Another topic to be dealt with is that of *how much nutrient to apply*. A recent survey in the Dairy industry has defined the need for extension staff to know what rates of fertilizer and what nutrients to apply.

In recent years we have become concerned with the *interaction of nutrients and animal production*. In many cases we may know how the pasture responds but we don't know how this is reflected in terms of animal production. It is an area which requires a great deal of resources and research.

However the most important question is that of *economics*. Particularly with the increased costs of fertilizers, the fertilizer component of pasture improvement costs is now much greater than it used to be. This whole question of how much to apply, now becomes a very pertinent question.

We are getting a diminishing level of staff and resources for our research so we have to rationalize and work specifically on those aspects which we feel are most important. What the Tropical Grassland Society has organized for this field meeting today is to bring together all those people who have expertise in the field of fertilizer use to review the subject and to see where we should put our research efforts in the future.

FERTILIZERS FOR PASTURES—WHICH NUTRIENTS TO APPLY

G. E. Rayment

Agricultural Chemistry Branch, D.P.I., Indooroopilly

Many factors affect which nutrients are, or should be, applied to pastures. They include:

- chemical and physical properties of the soil and of the nutrients themselves
- tolerance of pasture species to nutrient deficiencies and toxicities
- apparent responsiveness to fertilizers
- environmental conditions (moisture, temperature, day-length)
- competitive effects of other species
- extent of inputs and losses from the pasture system, whether planned or fortuitous
- chance of the fertilizer nutrient reaching roots of deficient plants
- stocking rate and stock management
- presence or absence of symbiotic associations with micro-organisms (rhizobium, mycorrhiza)
- extent of plant diseases, insect attack and parasites such as root nematodes
- probability of benefit, ultimately in economic terms

Property managers and their advisers must attempt to integrate these variables when assessing whether inputs of fertilizers and/or amendments are warranted. Local experience, visual symptoms, field experimentation, soil chemistry, plant chemistry, diagnosis via the animal, and modelling techniques have all been used to support this process. These methods of nutrient diagnosis are examined in this paper.

Local experience

The quality of local experience in assessing which nutrients should be applied to pastures is variable. It can be a hazardous exercise if factors known to influence response are not taken into account.

Reliability is probably highest when applied to pasture establishment on virgin land, supported by a knowledge of soil type and associated field experimentation. Local experience is particularly valuable when planning the strategic use of N. It also aids all other methods of nutrient diagnosis.

Visual symptoms

The visual appearance of pasture species may be used by the experienced eye to identify some nutrient deficiencies or toxicities. For example, N deficiency in grasses, as well as slowing growth-rate, commonly causes yellowing of leaves, especially lower leaves. In contrast, the upper leaves are inclined to yellow first when plants are S deficient.

Sole reliance on this diagnostic approach is not recommended because: a) disorders such as subsurface salinity and Al toxicity are difficult to predict from foliar symptoms; b) nutrient interactions can mask or be confused with symptoms of specific disorders; c) grazing may result in removal of indicator tissue; and d) pasture yield is usually significantly reduced by the time symptoms become evident.

Field experimentation

It is generally accepted that well controlled, on-farm, field experimentation provides the best indication of nutrient requirements, especially when they include grazing animals. However, results can be unreliable if: a) nutrient application rates were inappropriate; b) an uncorrected deficiency or toxicity existed at the site; c) the fertilizer formulation was unsuitable; d) stock condition and management differ from commercial practice; and e) seasonal conditions were atypical.

Major disadvantages are that field experiments are slow and expensive. Moreover, results tend to be site specific, unless measurements of soil, pasture and/or animals are made to allow extrapolation to similar locations and pastures.

While full scale field experimentation is not appropriate for routine diagnosis, the technique in the form of "test strips" is most useful. Test strips can help clarify "grey areas" which exist with all other diagnostic approaches. If used they must be observed closely; modified grazing preference as a consequence of the strip treatment may mask response.

Soil testing

Soil testing provides a rapid means of characterizing components of soil chemical fertility. When supported by soundly based interpretative data, it can be a useful indicator of which nutrients should be applied to pasture. It is particularly valuable when generalizations based on such things as soil type become unreliable due to natural variability or the impact of man.

Phosphorus has received most attention. There are published correlations for separating P-responsive from nonresponsive sites for several types of pastures in Queensland, including those based on white clover and Siratro. An indication of the probability of response to S, K, Cu and Zn fertilizer can also be obtained from selected soil tests. Tests for mineral N are more difficult to equate with N fertilizer requirements.

Importantly, soil testing is able to detect chemical conditions such as strong acidity, excess salinity, Mn and Al. The P sorption capacity of soils, a property which influences the rate of fertilizer-P required to correct P-deficiency, is best determined by soil testing.

Most estimates for pastures in Queensland are based on a sampling depth of 0–10 cm but sampling to 1 m has been recommended for S assessment in pastures containing *Stylosanthes* spp. Sampling to depths of 60 to 90 cm on an incremental basis is usually necessary for prediction of toxicities such as salinity and Al toxicity.

For large paddocks natural soil variation can be minimised over time by monitoring a datum area considered typical of the soil type and pasture under consideration. By sampling prior to fertilizer application at a similar time of year, fertility trends can be assessed in conjunction with planned and fortuitous inputs. Appropriate adjustments to usual fertilizing schedules can then be made in order to maintain nutrient levels at or above a certain prescribed level. The preferred soil P level for white clover based pastures in south-east Queensland is 35 mg kg^{-1} bicarbonate-extractable P.

Limitations of soil testing include: a) the technique is not immediate, it takes time to sample, transport samples to laboratories for analysis and to interpret results; b) care is necessary to obtain a representative sample from the pasture, free of nutrient contamination; c) depth of sampling may not be appropriate, especially for S, salinity, and Al toxicity assessment; d) correlations with response have some degree of uncertainty and are not available for all pastures, soils and environmental conditions; e) some analytical methods are inappropriate; and f) costs are incurred which can prove a deterrent.

Plant analysis

This technique finds most use in identifying specific problems where healthy and affected pasture species can be sampled in adjacent areas.

Critical ranges or concentrations for a number of elements and pasture species have been reported. However, these only apply when sampling procedures are strictly in accord with those employed when the indices were developed. There are strong correlations between levels of P, K and S in established white clover in south-east Queensland and response to topdressed fertilizers containing these nutrients. Details are given in the table below.

Some critical values or ranges (% in dry matter) for P, K and S in tops of established white clover plants grown in south-east Queensland†.

Element	Deficient	Critical	Optimum	High
P	< 0.30	0.30	0.31–0.40	> 0.40
K	< 1.1	1.1 –1.5	1.6 –2.5	> 3.5
S	< 0.17	0.17–0.19	0.20–0.30	> 0.30

†Require N% in range 3.5 to 4.5 before these standards apply.

In pastures subjected to heavy grazing pressure it is difficult to find suitable samples. One technique used to overcome this problem is to "cage-off" small portions of pasture on a temporary basis. As with soil testing, a monitoring approach from a prescribed datum area has many advantages.

Animal diagnosis

Measurement of animal product (milk, live weight gain) may provide indications that pasture production is below normal. Appropriate fertilizer inputs such as N and P may address the problem but much guess-work is involved if animal measurements are the only ones made. Some indication of nutrient deficiencies may be obtained from animal appearance. Alternatively chemical tests of faeces (P), blood (P, Cu), bone (P), liver (Cu) and saliva (Na) can be used. However, response to supplementation is the only unequivocal criterion for diagnosis.

Modelling

This computer-aided technique is best suited to the maintenance phase. General guides to maintenance fertilizer rates have been derived from summing nutrient loss rates. Alternatively, criteria can be developed from rate-on-rate fertilizer experiments or from dynamic models of nutrient cycles within ecosystems.

Losses considered include those in product and from leaching, erosion, run-off, volatilization, camping of stock, by immobilization, and as a function of stocking rate. More complex models attempt to allow for factors such as climate, soil fertility, fertilizer history, costs and prices.

Computer based fertilizer prediction models for tropical pastures in Queensland have not yet been applied in practice, although some are operating in southern and south-eastern Australia. It is too early to assess whether a maintenance fertilizer prediction model or models will prove successful at the farm and paddock level in Northern Australia. Longer-term botanical instability of most sub-tropical and tropical pastures is an additional complication.

HOW MUCH TO APPLY?

M. Gilbert

Department of Primary Industries, Mareeba

There are two questions which graziers frequently ask when considering the use of maintenance fertilizer on pastures. Firstly, "how much is enough?" Secondly, "how much is it going to cost?" Fertilizer useage on pastures has traditionally been low. In 1980–81 there were 150 000 ha of sown pasture fertilized in Queensland. If we assume that these pastures were largely confined to the 3060 dairy farms operating during that year, we get an average of 49 ha of fertilized pasture per farm. This is a reasonable estimate of fertilizer use in the dairy industry. Beef cattle producers, therefore, use little fertilizer and the reason for this is that the economic benefits of fertilizing pasture have not been clearly demonstrated.

The aim of fertilization at pasture establishment is to produce a vigorous pasture as quickly as possible in order to give an early return on the money invested. Subsequent fertilization aims to maintain the pasture in a productive state. In the past, maintenance fertilizer recommendations aimed to maximize pasture productivity in the belief that this would also maximize animal production. However, we must now look at levels of maintenance fertilization which are economically optimal.

The maintenance fertilizer requirements of pastures have often been assessed in small plot experiments using a range of fertilizer rates to determine the rate necessary to maintain maximum pasture yield. An advantage with this approach is that trials can be carried out at a range of sites differing in soil type and climate. However, these pastures are cut rather than grazed so that nutrients are discarded in harvested plant material. In a grazed pasture, nutrient losses are not as high as in the cut pasture owing to nutrient cycling through the animal. The obvious disadvantage with this technique is that results are not expressed as animal product.

Another approach is to determine fertilizer requirements for high animal production in a grazing experiment where fertilizer rate can be related to both pasture and animal productivity. Care should be taken that the results are not site-specific, and can be applied to different soils and environments, as these factors may influence the response to, and the residual value of, fertilizer.

The loss of nutrients in animal product is quite small in relation to the input as fertilizer. For example, when an animal of 200 kg empty body weight is fattened to 300 kg over twelve months at a stocking rate of one beast per 2 ha, 0.4 kg P ha^{-1} is lost from the pasture. In a dairy situation the estimated loss of phosphorus in producing 3500 litres of milk per lactation is 9 kg P ha^{-1} based on a stocking rate of 2.5 beasts per hectare. Maintenance fertilizer must compensate for nutrient losses in animal product, as well as losses within the soil and to camp areas.

Phosphorus fertilizer rates used for maintenance of pasture in Queensland can be broadly grouped into those appropriate to the wet tropics and those appropriate to the dry tropics. Wet tropical areas with high pasture production (20–24 t dry matter ha^{-1} $year^{-1}$) require phosphorus rates of between 15 and 30 kg P ha^{-1} $year^{-1}$. Dry tropical areas with lower pasture production (3–5 t dry matter ha^{-1} $year^{-1}$) require rates of from 5 to 12 kg P ha^{-1} $year^{-1}$. Commercial experience with grazed pastures has confirmed the usefulness of these recommendations. Generally these recommendations have been developed from field experimentation and experience and not from soil test data.

Many graziers and dairy farmers do not use soil testing as a means of determining maintenance fertilizer requirements for individual paddocks. Soil tests for phosphorus, for example, can be useful for assessing whether the phosphorus status is either extremely low or high, but lack precision and reliability when the phosphorus status is between these extremes. In many situations, therefore, the answer to the question "How much is enough?" is based on a mixture of local experience, previous fertilizer use and the cost. Ultimately, we would like to formalize this decision in a fertilizer prediction model (e.g. "Decide" model) which has been developed in southern Australia.

In the discussion on this topic it was suggested that applying fertilizer rates above that required for maximum pasture production may not be the most efficient way of supplying mineral nutrients to the grazing animal. It may be more efficient to feed the mineral as a supplement, because very high fertilizer rates would be required to lift nutrient concentrations in the pastures.

A FERTILIZER CASE HISTORY: THE SULPHUR STORY IN THE BEAUDESERT AREA

M. Hawley

Department of Primary Industries, Beaudesert

Soil analysis of the alluvia, alluvial and the upland basaltic loams, has shown that phosphorus levels are high (> 80 ppm), and in general, sulphur levels are low. I went through the duplicate soil analyses kept in the Beaudesert office and found at least 130 of them to have soil sulphur levels of less than 6 ppm. Most are in the alluvia, but there is a proportion in the basaltic uplands and sandstone country.

In the mid-seventies, various producers, commercial representatives and DPI personnel became interested in sulphur nutrition. One property in particular in the Kerry Valley commenced applying sulphur by air to hill country, with excellent visual results, both in the colour of the vegetation and increase in native legume content. Lucerne growers also commented that they did not get a response to superphosphate in the first year, but did in the second. The lack of response in the first year appears due to mineralisation of sulphur, and thus an increase in its availability, during cultivation and fallowing.

The advent of high density ryegrass systems highlighted what is perhaps a fragile situation for sulphur. In 1978 the first poor response to urea was identified both in cultivated and no-till situations. Application of Gypsum at 40 kg S ha^{-1} gave dramatic responses both at Beaudesert and Boonah. My recommendation for the district then emphasised the need for sulphur and the rate of 40 kg S ha^{-1} was arrived at by the fact that this is approximately the level applied in 2 applications of 250 kg ha^{-1} of Super over two years.

Last year an extensive area of oats was direct drilled on the high phosphorus basaltic soils with 125 kg Urea ha^{-1}. There was virtually no growth. Sulphur was applied through various carriers in small plots with quick responses. Subsequently 125 kg of sulphate of ammonia was applied with the desired results.

Site Plant Analysis

	S
Poor Growth	0.12%
Good Growth	0.20%
Ashes	0.31%

Soil levels of sulphate for the poor growth area were in the order of 6 ppm.

I have looked at some N.S.W. Department of Agriculture small plot work at Kyogle on similar soils. Sulphur was applied as Gypsum and Super at 28 kg S ha^{-1}, and the plots were oversown with Haifa and Safari Clovers. All sulphur plots produced 300–400% higher DM yields, with a high clover content, whereas the control and single Super plots showed poor clover growth. Soil S levels ranged from 6–8 ppm S and in one situation some response was obtained at 17.5 ppm S. Leaf analysis—Control:- 0.12%; 28 kg ha^{-1} S:- 0.21%.

Finally, Mr. J. Markwell of Ladybrook Pastoral Company is now using sulphur instead of Superphosphate. He comments that his tropical pasture (now Kikuyu) has responded well but it takes up to 12 months from the first application for the response to be expressed.

Further, after 3 years application of sulphur at 40 kg ha^{-1}, a 320 ha paddock with 100 ha of useless country included has increased its carrying capacity from 80 breeders with 80% calving percentage and ragged cattle to 158 breeders with 95% calving and well developed stock.

Costs per ha of sulphur application

Sulphur (Beaudesert)—$381 tonne	
Apply—40 kg per ha @ 38¢	$15.20
Application (air)	$6.60
	$21.80

I believe that although we are still learning about the deficiencies in the district, many of the alluvial soils have a sulphur problem. This property is an example of this problem; soil sulphur levels were of the order of 4 to 5 ppm S before sulphur fertilizers were applied.

Some producers have gone to extremes to correct sulphur deficiencies. In a lucerne area, a producer applied 125 kg S per hectare; his responses were rapid and dramatic and lasted for 3 years. This poses the question of what amount of S is really needed. How much do we need to apply because currently the recommendation is for 20 kg S ha^{-1} per year or 40 kg S ha^{-1} every two years?

In the discussion which followed, it was noted that elemental sulphur fertilizer is a slightly acidifying fertilizer. The effect of acidification will vary depending on soil type, and a soil such as this black alluvium is well buffered. Little pH change should result from this level of sulphur application. The price of sulphur application was also discussed. In Beaudesert, flying the Canadian Bright form of sulphur cost $20–21 per hectare at a rate of 40 kg S ha^{-1}. In North Queensland, the relative costs of sulphur application were, elemental sulphur as the cheapest, followed by dumped gypsum, then fortified super and finally single super.

FARM OPERATIONS AND PROBLEMS

H. BENSTEAD and M. HAWLEY

Property owner and District Agricultural Adviser, D.P.I., Beaudesert

Mike Hawley: There have been considerable problems on this farm over recent years. I have already spoken of the sulphur problem, but we have also isolated a soil compaction problem. With such a soil structural problem, correcting all fertilizer deficiencies will still leave major production problems. It is obvious that soil compaction could be a more widespread problem then we realise on old dairyfarms.

Howard Benstead: The property has an area of 127 ha, consisting mostly of black soil flats. There is a little bit of hill country where the house and dairy are situated and also a small area across the main road. Between 60 and 80 cattle are milked, with a total herd size of between 140 and 150. I feel that this is understocked, but like to err on that side so that I can practice culling. The cultivation area has been used for over 100 years.

I feel that the problem of this area is compaction as a result of the various cattle management practices used over the years. About 9 years ago, the paddock here was sown down to Whittet kikuyu. However, it never grew well and performed particularly poorly when dry weather conditions resulted in stress occurring. About 2 years ago, we used three different implements on the area, a spade hoe, a para-plough and a reversible mouldboard plough. These implements showed that there was a hard pan evident in the profile. A subsequent pasture of ryegrass, clare and ladino clover did not respond to these treatments, but this year's pasture appears better and seems to have responded to the deep cultivation. I bought a Wallace deep ripper this year, and prior to the sowing of the ryegrass, cultivated two thirds of the area again. Because of the heavy texture, the implement could only penetrate 15 cm, and it will be interesting to see if there is a response in pasture production to this extra deep cultivation.

This year's ryegrass was sown using the Department's triple disc sod-seeder. The area of kikuyu was slashed, and raked; then the young regrowth was sprayed with Roundup at 1 litre per hectare. The ryegrass was sown at 40 kg of seed ha^{-1}, and was fertilized with 300 kg of sulphate of ammonia per hectare and three weeks later with 125 kg ha^{-1} of urea. There are areas where the roundup was less effective because of rain two hours after application or where the spray application missed areas completely. These are obvious as kikuyu is still actively competing with ryegrass in these areas.

THE INFLUENCE OF FERTILIZERS ON ANIMAL PRODUCTION—GRASS/NITROGEN PASTURES

T. COWAN

Department of Primary Industries, Mutdapilly Research Station

At Mutdapilly, we are undertaking a project aimed at providing quality paddock feed throughout the year on dairy farms without irrigation. One method of doing this is to apply urea fertilizer to summer grasses, thus promoting rapid growth during wet periods and providing stand-over feed for cows during dry or cool weather.

In the major experiment we wished to look at the effects of five levels of urea applied to Callide Rhodes grass (*Chloris gayana* cv. Callide) on milk output. The levels of urea were equivalent to 0, 150, 300, 450 and 600 kg N ha^{-1} yr^{-1}. A decision had to be taken on what levels of other nutrients, especially P and K, were needed for these pastures. Applying luxury levels would increase costs and reduce the applicability of the results to farmers; applying too little may reduce the response to nitrogen. Samples of the top 10 cm of soil were taken from each of the 16 paddocks. These showed values for bicarbonate extracted phosphorus from 9 to 27 ppm, with an average value of 13 ppm. Acid extracted P averaged 8 ppm. Potassium averaged 0.34 m. equiv./100 g, with a range among paddocks from 0.17 to 0.87. Other average values, with range in parenthesis, were pH 7.2 (6.6–7.8), E.C. (ms/cm) 0.041 (0.027–0.064), Cl (ppm) 15 (8–36), Ca (m. equiv./100 g) 19 (9–26), Mg (m. equiv./100 g) 16 (13–19) and Na (m. equiv./100 g) 1.2 (0.6–2.0).

Our calculations of the maximum amounts of nutrients likely to be removed in milk and livestock were as follows.

Nutrient	*Removal* ($kg\ ha^{-1}\ yr^{-1}$)	*Input in grain and mineral supplement* ($kg\ ha^{-1}\ yr^{-1}$)
P	10	13 (8+5)
K	15	9
Na	5	8 (1+7)
Mg	1	4
Ca	12	1

We decided to apply 250 kg superphosphate ha^{-1} annually. This was on the basis of soil test and DPI advice. In addition 125 kg muriate of potash ha^{-1} was applied in the first year. This can only be described as insurance.

After two years the general results appear to be:

(a) dry matter response by grass as expected (22 kg DM/kg N)
(b) milk response as expected (4 litre/kg N in year 1, 9 litre/kg N in year 2)
(c) a marked dilution in P content of grass leaf, from 0.32% P at 0 N to 0.12% P at 600 N
(d) a dilution in K in grass leaf, from 1.64 to 0.99% DM, an increase in Ca from 0.55 to 0.65%, and no change in Mg (0.34%) and S (0.29%).

The dairy cow requires 0.4% P in the diet and the pasture is very deficient in this nutrient. However it appears the supplement may be providing sufficient P as the levels of production and efficiency of use of nitrogen fertilizer are consistent with values in experiments in more fertile areas. Also the pasture yield does not appear to be grossly restricted by the dilution of P. Despite the dilution, the K content appears sufficient for both pasture growth and milk production.

Obviously no decisions can be made on the basis of these results on the needs for P and K in a maintenance fertilizer program using nitrogen-fertilized grass pastures. We are left unsure of the minimum requirements for grass growth under grazing, of the animal's response to an increase in P in the grass compared with the provision of an inorganic P supplement, or if there is inefficient use of grass by the animal due to deficiencies of one or more of these nutrients. There is a definite lack of information in the area between field studies of grass responses under cutting and pen studies where the effects of nutrient supply as fertilizer or supplement have been investigated.

THE INFLUENCE OF FERTILIZERS ON ANIMAL PRODUCTION IN GRASS-LEGUME PASTURES

P. C. Kerridge

CSIRO, Division of Tropical Crops and Pastures, St. Lucia

Fertilization may influence animal production from grass-legume pastures.

Firstly, it will increase soil fertility and hence pasture productivity. Grasses respond to the nitrogen fixed by legumes but also require adequate phosphorus, sulphur and potassium to take advantage of the extra nitrogen. In fully sown pastures, sown grasses may not persist unless high soil fertility is maintained. In native pastures fertilized and oversown with legumes the higher productivity is often associated with a change in the composition and nature of the pasture and thus may take several years to occur.

Secondly, fertilization can influence animal production by improving the quality of the pasture. This occurs through higher intake and digestibility associated with the higher levels of nitrogen, phosphorus, sulphur and calcium in the pasture. Also, availability of higher quality components, such as the legume, may result in better utilization of poor quality forage.

A survey among dairy farmers in the Gympie district revealed that fertilization with superphosphate had a large effect on production. The use of 160 kg ha^{-1} superphosphate on sown temperate pastures, and on unsown pastures, raised butterfat production 54% by increasing production per cow and allowing more cows to be carried (Rees *et al.* A.J.E.A.A.H. **12:** 553). Likewise, fertilization has been shown to greatly increase beef production on spear grass pasture. Spear grass pasture alone gave an annual liveweight gain of 30 kg ha^{-1}, with superphosphate added LWG increased to 60 kg ha^{-1}, oversowing a legume without fertilizer gave 90 kg ha^{-1} and the addition of a legume with fertilization gave 150 kg ha^{-1} (Shaw and 't Mannetje, Trop. Grassl. **4:** 43). Further, the major impact of fertilization with oversown stylo took 5 years to have full effect. Another effect of fertilization is to increase fertility of breeding cows. On stylo-spear grass pasture, conception rate was lifted from 66% on unfertilized pasture to 74% with 125 kg superphosphate ha^{-1} and to 85% with 375 kg super ha^{-1} (Edye *et al.* A.J.A.R. **22:** 963).

Currently, at the Narayen Research Station we are investigating the role of small amounts of phosphorus and sulphur fertilizer on pasture and animal production. Phosphorus increases pasture growth in good seasons but has less effect in dry seasons. Nevertheless, animal production is increased in all years. Liveweight gain is related to the amount of phosphorus in the soil and pasture. Over the last 2 years an annual application of 5 kg P ha^{-1} (equivalent to 50 kg superphosphate) has resulted in a liveweight gain of 11.5 kg per animal per kg of phosphorus applied. As this effect appears to be due to higher phosphorus concentrations in the diet as well as increased pasture available, we will now determine to what extent the phosphorus response can be met by direct phosphorus supplementation to animals. However, it is likely that the cost of supplementation may be as great as that of fertilization of the pasture.

Finally, I would add that just as the impact of fertilization takes some years to have full effect so the rundown of pasture following cessation of fertilization will take place slowly so that yearly changes may be imperceptible.

ECONOMICS OF PASTURE FERTILIZATION

L. CLARKE

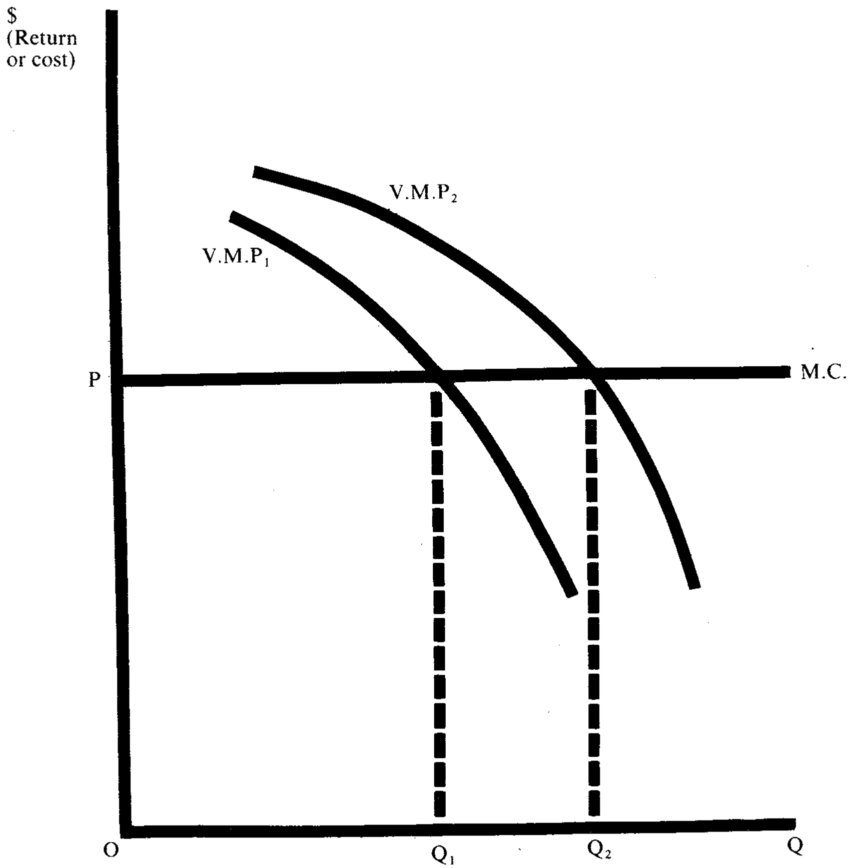
Department of Primary Industries, Ipswich

The economic criteria for deciding at which level we should apply some nutrient is to try to equate the marginal cost with the value of the marginal product. The marginal cost is simply the price of the input. If we are applying extra urea at a cost of 75¢ per kilogram, the value of the marginal product is the value of the extra production obtained from that extra nitrogen input. The problem comes in valuing the marginal product. Generally as we add extra input we get a decreasing product response so the value of the marginal product can be portrayed as a downward sloping curve (Fig. 1). So as well as all the considerations you have been given by the technical speakers, the price of the input (the marginal cost), and the value of the output are also important in determining what fertilizer application is "optimum" for a given situation. The economist says that they are the most important considerations, while obviously the animal people say it is the animal response.

If we look at the value of the marginal product, it is simply the multiplication of the price of the product (this may be influenced by outside factors e.g. quota requirements) and the production response (i.e. kg of milk or beef). This is what previous speakers today have been trying to define, i.e. how much milk or beef we will get from a given fertilizer input. Unfortunately, as we have seen, it is not a simple exercise to quantify that response.

The price of the product, a marginal price, is the manufactured milk price if you are on a quota system. This can undervalue the return if the production this year affects next year's quota. On the other hand, under a percentage system, the marginal price is the average price. Under this system, it pays to put on more fertilizer than someone on a quota system (the marginal price is higher), see Figure 1.

It is important that the economic optimum is borne in mind when treatment levels are being planned for research projects. So we want a change in output dollars which is greater than the change in input dollars. If we put 75¢ in we want to get at least 75¢ back. A response of more than 75¢ would mean that another unit can be added and a net "profit" made.



M.C. = Marginal Cost = price of unit of input
V.M.P$_1$ = Value of Marginal Product ("Low" product price)
V.M.P$_2$ = Value of Marginal Product ("High" product price)
Optimum $ return where V.M.P. = M.C.
(i.e. Q_1 or Q_2 units of input for low or high product price respectively).

FIGURE 1
Economic Optimum

Animal response to fertilizer is complex as has been indicated by previous speakers. Fertilizer is being applied to the pasture, and the yield and quality response by that pasture is influenced by various factors, including the level of other inputs and management factors. Pasture agronomists would be happy to stop there with the pasture response. However we have to put animals on the pasture and they will produce an animal response. This response will be dictated by another set of factors such as genetics, stage of lactation of the cow, health of the herd, level of other inputs such as supplements, management and the pasture utilization. The other important feature is that the response may be delayed. For example, it may increase over a number of lactations in the dairy situation.

Stocking rate is important. New Zealand dairy research results tend to emphasise per hectare performance, while Australian research results tend to concentrate on per cow production. In a pasture situation it is more appropriate to talk per hectare performance. Stocking rate is also important in the beef industry and in many cases we should be aware that the number of hectares available may be a limiting factor and so we should look at the response per hectare as well as the response per animal.

Another way of looking at this issue of the optimum input level is to ask the question: what response do I need to pay for what I have just done? Looking at the current returns for dairy farmers, and taking as an example the use of nitrogen fertilizer on grass pasture, we need to get about 8 or 9 litres of milk from the kilogram of nitrogen applied, to pay for that nitrogen application. The following is an example of the breakeven response:

Breakeven response for N on dairy pastures
N—75¢ per kg N applied (=$345 tonne^{-1})
Butterfat—4%; Freight—2¢ per litre

Milk price			Response needed to pay for addition of 1 kg N (litres)
$ per kg butterfat	¢ per litre factory	¢ per litre farm	
2.50	10	8	9.4
2.75	11	9	8.4
3.00	12	10	7.5
3.25	13	11	6.8
3.50	14	12	6.3
3.75	15	13	5.8
4.00	16	14	5.4

It should be pointed out that as researchers and extension officers we often talk in terms of average responses. We should try to qualify this by quoting, where possible, the probability distribution of a given response. This will give producers at least some measure of his chances of achieving a predicted response.

SUMMARY OF FIELD DAY

R. NUTT

ex D.P.I. Extension Officer and local Dairyfarmer

The use of fertilizer is important on any dairy farm, particularly on the more progressive ones. Dairying needs to be a highly intensive activity, and to make the most efficient use of our limited resources, we cannot rely on native soil nitrogen and the natural fertility of the farm alone. We must use fertilizer to optimise production.

George Rayment began by giving a basic rundown of the methods used in determining the nutrients needed for pasture health. He placed considerable importance on using local experience. This was borne out when Mike Hawley commented on the sulphur problems he had encountered in the Beaudesert area and his and the farmers' initiatives to sort out this problem. However George commented that local experience is not always reliable, serving only as a guide. Mike Gilbert drew our attention to the tremendous variability he had experienced in the results of soil tests taken from farm paddocks. He said that this is the real world, and that in this situation, soil tests are not a good indicator of fertility requirements.

Tom Cowan and Peter Kerridge spoke on the animal responses to fertilizer application. This is the area where farmers have to make decisions. It is the animal production response that they are interested in. Tom said that as plants may not respond to nutrients at levels required by animals, considerable savings could be made by feeding nutrients directly to animals as supplements. Peter Kerridge's results agreed with this, but also showed that phosphorus affected the animal through the plant as well as through diet supplementation.

Mike Hawley presented information on the sulphur story in the Beaudesert area. He showed there was a substantial saving to be made by fertilizing black soil flats with sulphur rather than Superphosphate, because sulphur, not phosphorus, was the nutrient limiting growth. Sulphur, although strongly held in acid soils, was not well fixed in alkaline soils. Mike posed the question of how frequently sulphur should be applied on deficient soils. It is an area for further research. Solving this question would certainly benefit producers. Howard Benstead told how deep ripping helped improve the physical structure of his alluvial soils which had become compacted after years of grazing under moist conditions.

Finally, Les Clarke spoke of the economic relationship between returns and fertilizer application. Producers do look fairly closely at what is put into the system, and try to match that with what they get out. Les provided the means of determining the economics of applying extra fertilizer.

Ray finished with the comment that there is no shortage of jobs for researchers to maintain farmland productivity.

BOOK REVIEW

Australian Soil and Land Survey Field Handbook. R. C. McDonald, R. F. Isbell, J. G. Speight, J. Walker and M. S. Hopkins (1984), (Inkata Press, Melbourne).

The ever increasing demand to conserve natural resources and to sustain and increase all forms of land use production has created a need for more precise and detailed information about soil and land. Sound land resource planning requires data in a form compatible for land use analysis. This Handbook has, for the first time in Australia, provided a basic reference to terminology and the means for consistent data collection to achieve this end.

The authors are to be commended for their provision of a much needed reference. They have surveyed comment from representative organisations involved in survey throughout Australia and have attempted to set limits for attributes to best accommodate the diversity of purposes for which soil and land surveys are conducted. Teachers, students and professionals directly or indirectly concerned with land use planning and production will find that this Handbook provides a comprehensive standard terminology for the systematic recording of soil and land features including those unique to the Australian environment. The manual is designed for use in the field and is presented in a plastic cover with colour coded page edges for easy location of the five major sections describing the properties of major soil and land attributes.

For survey purposes, the authors J. G. Speight and R. C. McDonald have defined the site concept which is arbitrary, but it does not provide the user of the Handbook with a clear guide to the spatial extent of a site which can be recorded as being acceptable for most survey purposes.

Landform description is well laid out with clear diagrams and is accompanied with glossaries to provide the user with explicit vocabulary for definition of basic landform elements and patterns.