MANAGEMENT TO MAINTAIN SOIL PRODUCTIVITY:

FERTILISER REQUIREMENTS OF GRAZED PASTURES

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SUMMARY: This paper deals with the critical factors governing the efficient use of fertiliser applied to pastures for animal consumption. Pastures in this context include native species with an introduced legume as well as fully improved pastures containing perennial grasses and legumes. The plant nutrients phosphorus and sulphur occupy most of the discussion, reflecting the very widespread and severe deficiency of both elements in most pasture growing areas.The critical factors under review include the identification of deficiencies, fertiliser application rate, choice of suitable product and timing of application. The importance of paying attention to these factors is discussed in terms of pasture productivity, sustainability and animal performance.

Livestock production throughout the higher rainfall areas of Australia is almost totally dependent on home-grown forage - chiefly from pastures. The gross value of production in NSW directly related to pasture supported livestock enterprises was estimated in 1992 (Archer *et al.* 1992) to be about \$3.3 billion or 56% of all the State's agricultural production. Pasture improvement to enhance livestock production has generally occurred in the higher rainfall areas of NSW, mostly since the end of World War Two, boosted by the wool price boom of the early 1950's. Improved pasture now accounts for about 30% of the total pasture area of NSW, or 50% excluding the western division, which is still largely rangeland. Native pastures (including rangelands) comprise about 70% or 13m hectares of the 19.3m hectares of agricultural land in the State.

On a regional basis, native pastures comprise about 40% of slopes and tableland areas and 85% of the western division. A higher proportion (50%) of the Northern Tablelands remains as natural pasture compared with 34% of Central and Southern Tablelands. This is at least partly attributable to the productivity of native pastures of the Northern Tablelands (Lodge & Whalley 1989) and grazing management systems designed to increase the abundance of cool season perennial native grasses at the partial expense of summer growing grasses.

In Southern slopes areas of NSW, pasture improvement has been mainly associated with the 'sub and super' approach. In the tablelands areas, perennial grasses were introduced as fertility levels from legumes and fertilisers increased or in many cases this took place concurrent with introductions of clovers, despite very low inherent soil fertility levels. In coastal areas, dairying and beef cattle production are the major livestock enterprises, also heavily supported by pasture improvement technology. On the South Coast substantial dressings of fertiliser with perennial rye grass have been regularly used while on the North Coast sub tropical species, as well as perennial rye grass form the basis of improved pasture with fertiliser again the key to achieving high animal production levels.

While improved pastures and fertilisers are frequently associated with tablelands and more fertile areas of the coast, in recent years fertiliser has produced large increases in plant and animal production from slopes locations. Crocker (1992) recorded significant responses to phosphorus and sulphur on native and introduced species on the North West slopes of NSW. Freebairn *et al.* (1994) reported on a series of trials conducted over a wide range of locations in the North Western slopes, Upper Hunter and the northern half of the Central West slopes and plains. 95% of the 76 sites in the series responded to either phosphorus or sulphur or a combination of both nutrients.

The inclusion of a legume into native pastures is recommended to improve production at most tableland and slopes locations and is recognised as the key, along with appropriate fertiliser to improved plant and animal production. Intensive dairy pastures with heavy nitrogen dressings rely less heavily on the legume component, but animal production nevertheless is enhanced by the presence of an appropriate legume to improve dry matter digestibility and increase both dry matter and protein intake.

The application of fertiliser to pasture has traditionally been directed towards introduced legumes and to a lesser extent perennial grass. Significant increases in pasture and animal production have been reported from a wide range of sites throughout the higher rainfall areas of Eastern Australia since pasture improvement took off in the late 1940's. More recently Sale (1994) re-affirmed the need for adequate levels of plant available phosphorus to support high levels of animal production, where introduced species formed the bulk of the sward.

By contrast the role and value of native pastures in tablelands and slopes areas should not be neglected (Robinson 1986). Significant pasture and animal production responses from native pastures have been reported by Lodge and Roberts (1979), Lodge (1979), Robinson (1976), Lodge and Whalley (1989) in Northern NSW and more recently by various workers in Central and Southern NSW (Garden *et al.* 1993). With the benefit of this research, and confirmation by commercial practice the role of native pastures has assumed greater significance in recent years. Significantly, the large increases in fertiliser prices since the mid-1970's and widely fluctuating livestock returns, notably sheep and beef cattle products, have caused much rethinking as to the long term economics of fully improved pastures, based entirely on introduced species. For these reasons, the content of this paper will be expanded to make reference to native species in addition to the more fertility demanding exotic (introduced) pasture species.

Critical aspects of pasture fertilisation

Previously quoted research solidly backed up by producer experience since the very early days of pasture improvement highlight the widespread and severe deficiencies of phosphorus and sulphur over vast areas of the higher rainfall country of NSW. In addition, many coastal areas lack potassium as well as those inland areas subject to repeated product removal (hay, grain, etc.). Trace element deficiencies are also important, notably molybdenum in the more acid soils as well as boron, and occasionally copper and zinc on neutral to alkaline soils. Many tableland, slopes and coastal soils respond to lime where a combination of low pH and cation imbalance provides a very hostile environment for many commonly introduced pasture plants. The following discussion will concentrate on the two major deficiencies of phosphorus and sulphur, but local knowledge, soil analysis and research should all be employed to identify other nutrient deficiencies and guide remedial action.

The aspects of fertiliser use considered to be of most importance for effective plant response are likely to be:

- Identification of deficiencies
- Rate of application
- Suitable product choice
- Timing of application

These critical factors relate to an improved or semi-improved pasture responsive to added nutrients. Purely native pastures, with low capacity to respond should at least have a legume present to increase responsiveness and thus the economic basis for fertiliser use.

Identification of deficiencies

Apart from sound local knowledge, which is generally an excellent guide, other means of determining nutrient deficiencies include soil tests and strip trials. In some cases, tissue analysis may be useful.

Soil tests do not provide all the answers, rather they provide guidelines as to whether a deficiency exists but should not be used to determine rates of fertiliser. Several tests are available for phosphorus. The two most commonly used in NSW are the Bray No. 1 and the Colwell tests. The Bray test is preferred on acidic tableland soils (Holford & Crocker 1988), however local experience and knowledge of soil type also allow the Colwell test to be a useful guide on acidic soils where the critical level for phosphorus response is known to fluctuate with phosphate sorptivity.

Until recently, soil testing for sulphur has been most unreliable when extractants that remove only sulphate from the soil were used. A significant breakthrough occurred in 1992 with the introduction of the KCl 40° test that accounts for the more readily available component of organic sulphur as well as the sulphate component (Blair *et al.* 1991). This test, now gaining wide acceptance with its availability through several commercial laboratories in NSW has provided agronomists with more precision in making fertiliser recommendations. It coincides with an increasing number of high analysis fertiliser products appearing which contain varying amounts of elemental sulphur. The new sulphur test has already improved efficiency in pasture topdressing practice.

Soil testing for trace elements is essentially of no value for determining fertiliser requirements, but is an important tool in identifying and correcting acid soil problems. Soil acidity and the use of lime has been thoroughly researched by many workers including the early work of Spencer and Roe (1962) and more recently comprehensively summarised by Cregan *et al.* (1989). Before any fertiliser program commences, the pH status and cation levels of an area should be investigated, otherwise responses to fertiliser additions may be very severely restricted.

Local trials can be very useful to assess a response to nutrients thought to be deficient. They do not need to be of sophisticated research design, but for best results should be carefully conducted on representative sites, with responsive species (preferably a legume) present and with several rates of each nutrient used to assess degrees of response. Grazing animals must be excluded from the trial area for at least six months, or up to twelve in the case of lime trials.

Tissue analysis is not widely conducted on plants from grazed pastures and still requires considerable research to provide for an accurate interpretation of results. It is an expensive procedure and would only be contemplated in unusual circumstances or under tightly controlled research conditions.

Rate of fertiliser application

All too often, producers and probably many agronomists think in terms of how much fertiliser has been applied to a pasture, without taking into account the equally important aspect of product removal. Tables 1 and 2 serve as a guide to product removal and other losses of nutrients under various agricultural activities.

It can be easily seen from these data that the traditional rate of 125 kg/ha of single superphosphate suppling 10.7 kg P and 14.3 kg S, even applied annually will not significantly increase phosphate levels on many pasture soils with a stocking rate of 8-10 DSE/ha. This is assuming that there is a significant removal of animal product as opposed to the minimal product removal that may occur with a wool growing enterprise. A wether flock removes relatively little phosphorus and sulfur as long term studies of soil fertility run-down at the C.S.I.R.O. Research Laboratory 'Chiswick' near Armidale have shown (K. Hutchinson *pers. com*) These results were derived from a site with a substantial fertiliser history (3.75 t/ha of single superphosphate) where animal production did not decline for ten years after fertiliser applications ceased. However from the 11th year animal production declined sharply. By contrast, under a more demanding animal enterprise (breeding, finishing, *etc.*), at least 250 kg/ha of single super should be applied annually to the more responsive paddocks at the expense of those carrying mainly inferior native grasses and no legume. The more valuable and highly productive native grasses, notably *Microlaena* and *Danthonia* are certainly responsive to fertiliser but are less demanding than the introduced perennial grasses and are thus more resilient and forgiving of intermittent fertiliser applications (Wyndham & Wyndham 1992).

Table 1. Loss of phosphate from a grazed perennial pasture on a medium textured soil (Duncan 1992).

Stocking rate DSE/ha	P removal kg P/ha
5	6
7	8
10	12

Table 2. Loss of nutrients according to different agricultural practices (M. Duncan *pers. comm.*).

Product	Typical nutrient removal (kg)		
	P	S	K
Legume hay (1 tonne)	2.5	2.0	10.0
Wool (5 kg)	0.02	0.2	trace
Meat (50 kg)	0.4	0.4	0.3
Milk (1000 L)	1.0	0.6	1.5

Increased rates of fertiliser have recently been promoted by researchers at the Pastoral and Veterinary Institute at Hamilton, Victoria (Sale 1993). The effects of combining high rates of phosphorus and high stocking rates on animal production from pastures containing responsive pasture species are reported to be spectacular. Dairy farmers have long been well aware of the benefits of heavy applications of phosphate on milk yield and some western Victorian producers are observing similar improvements in wool and beef production. Whether such a response will occur in non-Mediterranean climate areas of northern NSW is not clear. Several trial sites to measure pasture and animal responses to high phosphate applications have now commenced in the Walcha district of the Northern Tablelands. Drought conditions in 1994 prevent any preliminary conclusions to be made.

Another important factor determining the most efficient rate of fertiliser is the nature of the livestock enterprise. Clearly a self replacing merino flock will be less demanding than a prime lamb enterprise, reflecting the need to have fertile, highly productive pastures for the lamb enterprise. Table 2 illustrates this aspect of nutrient removal and explains in part the drift by tableland producers from highly demanding, fertiliser dependent livestock enterprises to those that function adequately at a reduced level of soil fertility and pasture production.

Choice of product

Having determined the nature of deficiencies and where possible the magnitude, the next decision concerns the most appropriate product.

Phosphorus is deficient in the majority of soils in NSW. In terms of phosphorus, the choice essentially will be between water soluble and the citrate insoluble form. Single superphosphate, triple superphosphate and the high analysis products all contain the majority of their phosphorus in the water soluble form. This means phosphorus is immediately available to the growing plant, provided other factors are available (light, temperature, *etc.*). Water soluble phosphorus is generally considered to be the most effective means of supplying phosphorus to pastures in otherwise deficient soils.

Recently, reactive phosphate rock (RPR) has been researched for use in Australia, despite the phosphorus being non-water soluble, *ie.* in the citrate insoluble form. It is important to differentiate between phosphate rock used to manufacture superphosphate and RPR's. The former is not suitable for direct application to pastures because the phosphorus is insoluble and release too slow to benefit the growing plant. RPR's contain more carbonate, are 'softer' and are able to release phosphate slowly to plants making use of soil acidity and moisture. Research at 27 sites currently underway in Eastern Australia is providing valuable information as to the effectiveness of RPR's (Sale 1994).

Preliminary results indicate a similar behaviour of RPR's in Australia as previously conducted New Zealand research (Edmeades *et al.* 1991), that is, a period of 3-5 years is needed to fully exploit the phosphate from a good quality RPR and depending on the soil phosphate status, this would result in a penalty of reduced pasture growth. The only means of reducing this penalty would be to significantly increase the rate of application. At the current cost of RPR's, this would not be considered by many producers to be a viable course of action. A further deficiency of RPR's concerns the absence of sulphur and the subsequent cost of adding this nutrient. At this stage, RPR's appear to have a limited role; in areas where phosphorus status is close to the critical level, in high rainfall areas and where soil pH is below 5.0 ($CaCl_2$). Depending on circumstances and cost, RPR's may find a larger market when combined with a water soluble source of phosphorus, provided they are cost competitive and sulphur is added.

New phosphate products have entered the market in recent years, all substitutes for the traditional single superphosphate (Crocker & Duncan 1993). They offer advantages in physical handling and spreading and are about 8% cheaper than single superphosphate. They are based on triple superphosphate, containing water soluble phosphate with added sulphur. The sulphur is between 80% and 95% elemental in form. These products may not be preferred over single superphosphate on soils with little organic sulphur accumulation where the quickest response is sought. Otherwise their performance has generally been found to be at least comparable to single superphosphate or superior on some lighter textured soils where sulphate sulphur readily leaches.

Sulphur is the other major deficiency of pasture soils in NSW (Duncan, Crocker) and is taken up by plants as sulphate (the gypsum form). The elemental form, as found in the high analysis phosphate fertilisers, needs to be converted by soil inhabiting bacteria to the sulphate form for plant uptake. This conversion (oxidation) takes place quickly in warm moist soils provided sulphur particles are small (less than .25mm). While sulphate sulphur is immediately available to an actively growing plant, large quantities will leach after rainfall, especially in the lighter soil types. Under these circumstances, elemental sulphur, provided it is sufficiently finely ground, will provide a more continuous supply of sulphur and may be a more efficient means of maintaining the sulphur status once the initial sulphur deficiency is corrected.

Rates of sulphur to overcome deficiencies range from an initial application of 15-20 kg/ha, to an annual application of between 5 and 10 kg/ha for maintenance. The KCl-40 sulphur test will enable more accurate diagnosis of deficiencies and more cost effective use of fertiliser to the extent of using triple superphosphate at considerable saving where sulphur is found to be excess to plant requirements. Recent research conducted at the University of New England (G. Blair *pers. com*) has shown that the important trace element molybdenum will not be readily taken up by plants where large amounts of sulphate sulphur are available. This emphasises the need to accurately determine sulphur requirements before choosing the most appropriate product in molybdenum deficient areas. Table 3 provides details of a representative range of products to correct phosphorus and sulphur deficiencies.

Table 3. A range of more commonly used fertiliser products for phosphorus and sulphur deficient areas.

Product	% P		%S	
	Total	Available	Elemental	Gypsum
Triple Superphosphate	20.7	20.0		1.5
Single Superphosphate	8.8	8.6		11.5
Pasture P	17.3	16.8	7.2	2.3
Pasture Plus	17.3	14.7	12.2	3.0
Goldphos 10	18.6	18.0	10.0	
Goldphos 20	16.6	16.0	20.0	
SF 45	5.5	5.0	35.7	8.9

Timing of fertiliser application

Factors influencing the decision to apply fertiliser to pastures are frequently those associated with cash flow and taxation rather than agricultural science. As a general statement, the timing of application is significantly less important than such factors as type of pasture, presence of responsive species, livestock enterprise, rate of nutrient applied and magnitude of deficiencies. On very phosphate deficient soils for example, it would be argued that any time of the year is a good time to apply phosphate. It would also be reasonable to put forward an argument in favour of boosting germinating seedlings of sub clover with a March topdressing or a summer application to reduce the risk of spring bloat where white clover is the dominant legume. Further, the application of fertiliser to coincide with an active period of plant growth, rather than when plants are stressed by frost, waterlogging or drought would be a sound approach. In this way more nutrient would be taken up by an actively growing plant for animal consumption and less would find it's way into the inorganic non available form.

The recent trend towards high analysis products for pasture topdressing containing appreciable amounts of elemental sulphur demands more attention to timing. As previously stated, elemental sulphur requires microbial action with adequate conditions of moisture and temperature to bring about a conversion to the plant available sulphate form. In general terms, the conditions that favour plant growth, also favour the oxidation of elemental sulphur. Accordingly, on very sulphur deficient soils, application of elemental sulphur, irrespective of the particular fertiliser product, will provide a quicker release of plant available sulphur if application takes place from spring until autumn avoiding very dry or waterlogged soil. On soils with a known build up of organic sulphur from previous fertiliser applications or where soil tests indicate reasonable soil sulphur, timing is not so important.

Timing of application for phosphorus is less important, but some factors are worth consideration. Increases in phosphorus have been recorded during long dry periods and are thought to be due to continual mineralisation of organic matter with minimum uptake by plants. As a result, there is generally some inflated phosphorus levels following a drought which will return to pre-drought levels following 3-6 months of improved plant growth.

Decreases in soil phosphorus levels following very wet periods are probably due to increased phosphorus sorbing capacity of soils as a result of reducing conditions in waterlogged soils (Vimpany & Bradley 1980). Under these conditions, a spring application of phosphate is likely to be more efficient than an application in autumn prior to winter waterlogging. This is likely to be of greater significance on poorly drained soils derived from slate and shale than better drained basalt soils.

Conclusions

Where plant nutrients are deficient, fertiliser is undoubtedly the key to improved plant and animal production. The presence of responsive species in the pasture is vital to provide the basis for such improvement. The legume component is the foundation for improvement whether native or introduced grasses are the companion species. Soil type, fertility, livestock enterprise and rainfall largely determine the choice of the companion native or introduced grasses.

The critical factors determining efficient fertiliser use are:

- identification of deficiencies;
- rate of fertiliser application;
- choice of suitable product; and,
- timing of application.

The identification of nutrient deficiencies requires local knowledge, soil analysis and local trials while tissue analysis has a limited role.

Rates of application are traditionally too low and should be governed by magnitude of nutrient deficiency, product removal, livestock enterprise, pasture type and available finance. High fertility demanding perennial grasses, notably the introduced species, are more often than not regularly under fertilised and this is seen as one of the reasons for pasture decline since the mid-1980's. By contrast New Zealand producers working under similar economic constraints have to a large extent successfully maintained improved pastures with high levels of fertiliser applications. The generally more favourable climate in most of the agricultural areas of that country provides the basis for pasture responses to fertiliser. While acknowledging a climatic difference, the New Zealand principles of boosting pasture and animal production with adequate fertiliser are relevant and should serve at least as a guide for producers in the grazing areas of Eastern Australia.

The choice of fertiliser has become more complex in recent years as an increasing range of products supplying phosphorus and sulphur has become available. The water soluble form of phosphorus is preferred in the majority of cases to the less soluble products based on citrate soluble phosphorus or reactive phosphate rock. Research currently underway to evaluate the role of RPR's confirms a slow release of phosphorus from these products and an accompanying penalty in reduced pasture growth. A combination of RPR and water soluble phosphorus may have merit under certain circumstances provided sulphur is added where required and the product is cost competitive with other phosphate fertilisers.

Sulphur is an important deficiency in many pasture growing areas and should be applied either in the readily available sulphate or the slower release elemental form. Elemental sulphur has been shown in trials and commercial practice to be an efficient means of supplying sulphur and on some soils may be preferred in future over the sulphate form, provided an initial significant deficiency has been at least partly corrected.

The timing of fertiliser application is not seen to be as critical as other factors in terms of fertiliser efficiency. Where elemental sulphur is used, an acceptable oxidation would be expected under similar conditions of moisture and temperature as those that favour plant growth. Otherwise, release of sulphur would be retarded, but this usually coincides with reduced plant growth. For this reason, a mid-winter application of elemental sulphur, provided it is sufficiently finely ground, would be slightly less effective in the short term than sulphate sulphur.

Timing of phosphorus applications is best made to coincide with a flush of growth, especially the legume. Evidence is presented to suggest that an autumn application of phosphorus in poorly drained soils prone to water logging may result in reduced availability of phosphorus to the growing plant. Under these circumstances, a spring application would be preferred.

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