PLANT NUTRITION FOR SUSTAINABLE GRASSLANDS PRODUCTION: A BALANCED OVERVIEW

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At the outset, it should be pointed out that truly sustainable agricultural production is unlikely to come about in current social, political and economic contexts. The pressure of increasing human population on the finite resources, particularly fossil energy, required to produce, process and distribute food and fibre will eventually exhaust these resources. However, within this pessimistic but realistic context, much can be done to improve the sustainability of grasslands production.

For the purpose of this paper the concept of sustainable production is defined as implying a matching of the nutrients flowing from the system, in terms of animal products and erosion and other outgoings, with nutrient supply, without reducing the bank of those nutrients in the soil. Most soils theoretically have enough nutrients to support thousands of years of production, but these nutrients are in a relatively unavailable form and their rate of release is sufficient to support only a low level of production which may not be economically viable where land supply is limited and farming costs high. If higher sustainable production is required in the long term (for shorter term production it may be possible to stimulate more active release of nutrients from soil reserves by encouraging microbial activity) nutrients will have to be added as fertilisers

A good example of the effect of fertiliser on pasture production over an extended period (34 years) is shown in the results of an experiment on irrigated pasture in New Zealand (Nguyen et al, 1989) After an initial large decrease, the result of ceasing fertiliser input after several years of fertilising during the establishment of the pasture, herbage yield without fertiliser declined only slightly over the 34 years. (Fig 1). However, over the same period of time, yield was approximately trebled by annual applications of 188 and 376 kg of superphosphate per ha. When, after six years of applying fertiliser at these rates, there was no further fertiliser application, herbage yield declined steeply to reach after 29 years a low which was little different from the production by the unfertilised pasture.

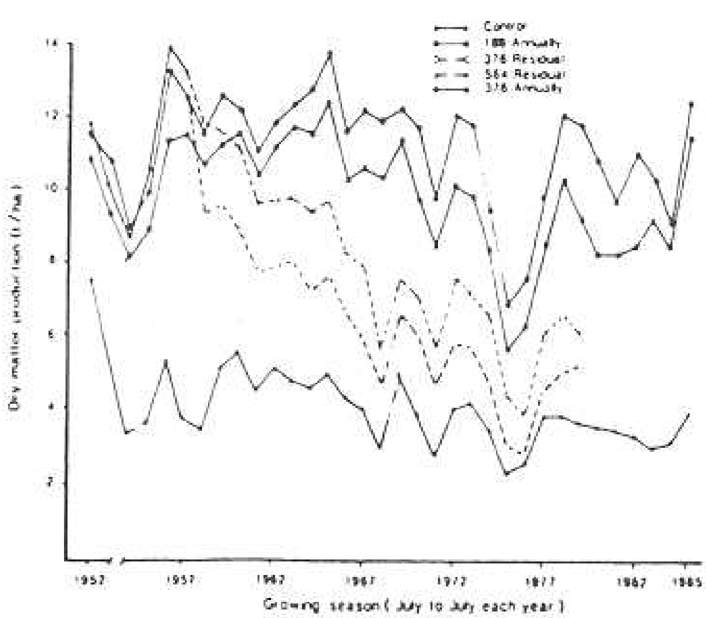

Fig. 1 Effect of unfertilised control, two rates of annually applied superphosphate (188 and 376 kg/ha), and two residual superphosphate (376 and 564 kg/ha) treatments on annual DM production over 34 growing seasons (from Nguyen et al. 1989)

Fertiliser types:

A convenient way of classifying fertilisers is shown in the following diagram:

- Fertilisers
  - "Synthetic", Artificial", "Chemical"
  - Non-"Synthetic", - "Artificial", - "Chemical"
    - Organic
    - Inorganic

"Synthetic, "artificial", "chemical" fertilisers are manufactured products involving some human-controlled chemical process - e.g., superphosphate, ammonium nitrate, etc.

Organic fertilisers are derived from naturally - occurring organic materials such as farm yard manure, blood and bone, seaweed, etc.

Inorganic fertilisers are mined from naturally occurring rocks and minerals such as phosphate rock, dolomite, gypsum, etc.

Phosphorus fertilisers:

Although potassium, sulphur, magnesium, etc., are all required for pasture growth and may be deficient in some soils, the bulk of farmer experience and research indicates that inadequate phosphorus (P) uptake is the major nutritional constraint to Australian grasslands production; therefore, this paper concentrates on phosphorus fertilisers. These are of two major types - those containing mainly water soluble P, such as superphosphate, and those containing mainly water - insoluble P (in the form of calcium phosphates) such as various phosphate rocks.

When a water-soluble P fertiliser is applied to pasture a certain amount of the P can be quickly taken up by the plant, and the rest immobolised in various ways, e.g., by forming insoluble aluminium or iron phosphates. P from a water-insoluble P fertiliser is less readily taken up; e.g., an experiment near Yass in 1989 showed the P content of unfertilised clover to be 0.11%, with 40kg of P/ha as phosphate rock it was 0.15%, and as superphosphate it was 0.17%. Research indicates a strong relationship between P uptake and plant yield.

The place of quickly-soluble P fertilisers vs. that of slowly-soluble P fertilisers is still a matter of much controversy even (or especially) amongst scientists, let alone manufacturers and agents. An example of this is seen in recent issues of the Australian Journal of Experimental Agriculture in the review by Bolland et al (1988), its criticism by Quinn (1989) and the rebuttal of that criticism by Gilkes and Bolland (1989). Most of the scientific literature indicates that phosphate rocks, even the more reactive ones, are far less effective than superphosphate for both first year and long term (residual) responses. However, recent field experiments near Yass, and glasshouse experiments at Canberra, suggest that the first-year disadvantage of some less soluble P fertilisers may not be as great as that discussed in the review of Bolland et al (1988), and that in subsequent years there may be little difference between the two fertiliser types. Obviously, more research is needed in this matter.

Superphosphate and soil acidity:

The acid soil problem, associated with long periods of subterranean clover fertilised by superphosphate, is now widely recognised. However, current scientific opinion is that, although the acidity (c. pH3.5) of superphosphate has a short term and localised effect around the superphosphate granule, it is not in itself responsible for soil acidification. Rather, soil acidification is more readily explained by the production of organic acids and nitrate from the stimulated growth of the legume. Certainly, it is difficult to directly associate pH decline with, only, the quantity of superphosphate applied. In the Australian literature I can find only one example of this (Horsnell 1986) where the single application of 1.1 t of superphosphate/ha resulted in a pH drop; and this only when the pH was measured in water. The acidifying effect in this case was due to the gypsum in the superphosphate. In an experiment near Yass (Dann and Fischer, unpublished data), a total of 1.6 t of triple superphosphate/ha over 4 consecutive years had no effect on pH.

This is not to imply that superphosphate will in future be the best fertiliser to use on NSW acid soils. Some of the products coming on the market have a definite neutralising value. At economic application rates they are unable to rectify soil acidity to the extent that a large (say 2.5 t/ha) rate of lime does; but theoretically they should slow the rate of acidification. The use of deep rooting perennial plants to absorb excess nitrogen in the soil profile could also be another approach to reducing soil acidification.

Phosphorus fertilisers and toxic elements:

The main concern in this respect is cadmium (Cd) but fluorine (F) and possibly zinc (Zn) could theoretically pose health problems. Cd is associated with the phosphate rock used directly, or for superphosphate manufacture. Phosphate rocks vary widely in their Cd content, e.g. (as mg/kg) 70-89 for Nauru, 42 for Christmas Island, 21-36 for Nth. Carolina, and 0.5-7.0 for Duchess, rocks. Obviously, use of low-Cd rock is important and the Australian fertiliser industry is working towards this.

Organic fertiliser:

Farm yard manure, poultry litter, etc., are widely used in overseas countries, and probably act in any combination of the following ways - physically in terms of improving soil structure via microorganisms, enzymatically or by some similar biological pathway, and most importantly, by nutrient supply. Composition of FYM and other organic fertilisers varies greatly, say 0.1 to 1.7% for N, 0.1 to 0.9% for P and 0.1 to 1.1% for K. Relative to inorganic fertilisers these contents are small and therefore large amounts of manure are needed to supply the same quantity of nutrients as provided by concentrated fertilisers - e.g. 8.8 t of FYM at 0.1% P is required to provide the same amount of P as 100 kg of superphosphate at 8.8% P. Therefore, high rates of farm yard manure are used in overseas countries - e.g. in England and Wales in 1957, about 6 t/ha. In 1987-88, about 1.6 m t of superphosphate were used on Australian grasslands, equivalent to about 130 m t of cattle manure, the production of which would require about 4 m steers. It could be, however, that less P supplied in FYM would be required than that in superphosphate, if the latter form of P is more quickly and firmly immobolised.

"Growth promotants":

These are products derived from fish, seaweed or bacterial cultures or other organic sources and applied in amounts which are very small relative to those of fertilisers. As the amount of nutrients applied is therefore very small, if a pasture response does occur it is presumably via some enzymatic or other organic pathway. Numerous scientific studies on the effect of promotants on plant growth, have given conflicting results; however, because positive responses have been demonstrated, at times, the role of these products should be further investigated. "Biodynamic" preparations made from a variety of materials ranging from finely-powdered quartz to animal manure buried over winter in cows' horns, are also claimed to improve yield and quality of agricultural produce. It is difficult to devise acceptable research to separate the real value from the mystical connotations of biodynamic production.

Cultivation:

Cultivation - including non-inversion tillage - can sometimes stimulate pasture response; this can be due to a number of reasons including microbially-induced nutrient release, better root penetration, nutrient entrapment, etc., but the main reason is improved soil moisture. If this occurs when soil temperature is adequate, as in early autumn, substantial increases in pasture production can occur.

Soil macro and micro organisms:

Soil is habitat for vast numbers of organisms, ranging from microscopic bacteria to larger organisms like earthworms and wombats. It has been estimated that the weight of organisms beneath a pasture may be equivalent to about 25 cows/ha, and they contain large quantities of nutrients - e.g., up to 75 kg of P/ha. These nutrients are released by excretion from, or death of, the organisms. For example, some New Zealand research indicates that annual turnover of N and P from the excreta and mucous, and the death, of earthworms could total 8-42 kg of N, and 2-9 kg of P, per ha. There is evidence that "synthetic" fertilisers do not destroy earthworm populations, and can increase microbe populations.

Minor elements:

The value of very small applications of an element such as molybenum is well accepted. Application of small amounts of selenium may lead to better animal health, boron to improved clover seed set, and copper to enhanced coat colour and fertility in cattle.

Animal production responses to superphosphate:

Production of more herbage, in response to superphosphate, does not necessarily mean that animals will produce more. This is especially so if there are insufficient animals to consume the additional herbage. Also, if the increased herbage is of inferior quality, because of, say, changed botanical composition, animal production may not increase in proportion to the quantity. Experiments to measure animal production responses to fertiliser are costly to conduct, and relatively few have been done in Australia. In NSW, several experiments have demonstrated animal production responses to superphosphate;

several others have not. For example, Curll (1977a & b) showed increased wool production, ewe liveweight and lamb production, and steer liveweight, and improved gross margins, following superphosphate application to perennial pasture. On the other hand Kohn (1974) and Southwood et al (1976) concluded that there was no economic animal production response to superphosphate applied to annual pasture, which had previously received 700 - 1000 kg of superphosphate per ha, in a clover ley-cropping system. This was mainly due to a change to more grasses and less clover in the pastures receiving superphosphate.

Conclusion:

This paper is leading to an obvious, and increasingly more topical, question - should pasture nutrition be via 'synthetic', 'artificial', 'chemical', etc., fertilisers, or through non-'synthetic', etc., fertilisers. The answer to the question lies partly in personal philosophical attitudes. Most of the commercial soluble phosphorus fertilisers (use of nitrogenous fertilisers on grassland should be discouraged, if legumes can perform the same function) appear not to present the intensity of environmental threat posed by many of the more powerful pesticides currently used in agriculture. If a producer has reasons, philosophical, ethical or commercial, not to use a water-soluble-phosphorus fertiliser like superphosphate, there are options - e.g. phosphate rock or organic fertilisers. However, a number of factors should be considered when contemplating these options.

The often poorer, and often substantially so, efficiency (in terms of immediate, and residual, action) of phosphate rocks when compared with superphosphate in experiments has to be considered. To obtain production responses similar to those from superphosphate application, high rates of phosphate rock may need to be applied. On the other hand, highly reactive phosphate rock on a soil following large applications of superphosphate to legume-based pasture may be a satisfactory alternative to superphosphate. More research is meeded in this field.

The use of organic fertilisers on Australian broad acre pastures raises several questions, particularly if the fertiliser comes from intensive animal production. From where did the nutrients come to feed the animals? Obviously, from some other agricultural areas, the soil minerals of which were mined and transferred, via the animals, to the area receiving the manure. What levels of biocides may be in the manure, as a result of medication and other additives given to the animals? What are the logistics of gathering and distributing the huge amounts (say 130 m t of cattle dung) if this is used to completely replace the concentrated fertiliser currently used on Australian grasslands? Ideally, for sustainable grasslands production, minerals removed in the form of animal products from those grasslands should be returned to them. This need for recycling is a matter, not only for farmers, but for society as a whole. Unfortunately, it may not be perceived as having high political priority

Finally, it is worth while reiterating the principals of grasslands nutrition that are required for sustainable grasslands production. For low levels of production, unassisted release of nutrients from soil reserves may be adequate and, for practical purposes, sustainable in the long term. For higher levels of production, increased nutrient release resulting from enhanced microbial activity may be adequate in the short term; but for sustainable long-term high levels of productivity, it is necessary to balance nutrient removal in product and other outgoings with inputs of externally-sourced nutrients provided by some form of fertiliser or manure, or to recycle those nutrients to the areas from where they came.

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