SOME CONSEQUENCES TO DAIRY CATTLE OF THE
ADDITION OF NITROGEN FERTILIZERS TO DRYLAND GRASS PASTURES
IN SOUTH EAST QUEENSLAND

G.K. REASON*, K.R. McGUIGAN** and P.D. WAUGH***

SUMMARY

A study to determine the response in milk production and other animal, pasture and soil parameters to inputs of nitrogen fertilizer of 50, 100 or 150 kg N per cow per year was undertaken over 4 years on 12 commercial dairy farms in south-east Queensland.

The results as measured by these parameters has been generally positive (Reason et al 1989), the diversity of sites achieved via 12 commercial farms has enabled an assessment of a number of "failed response" situations, and the investigation of perturbation in animal performance as a result of interactions between nitrogen inputs and mineral nutrient availability to the dairy cow.

Specific problems which have occurred relate to bloat in cows grazing nitrogen fertilized grass pastures in certain conditions, and impaired reproductive performance. These conditions have been related specifically to low sodium and low calcium levels respectively in the diet. Of a more disturbing nature' is a general trend towards lower level of metabolites over time with the continued use of high rates of nitrogen.

The influence of variable animal performance on adoption of nitrogen fertilizer technology cannot be ignored. To remain cost competitive, the sourcing of feed components from pasture inputs will continue to play an important role.

INTRODUCTION

It has long been recognised that milk production achieved from the pasture component of farm feed systems has limited dairy production in sub-tropical and tropical Australia. Poor pasture feed quality and inappropriate species or management practices are some of the factors limiting milk production, particularly in autumn. Research has shown that tropical pastures are not capable of achieving milk production levels per cow similar to those recorded for temperate pastures (Stobbs 1971, 1975) and this is associated with inherent sward structure (Stobbs 1974 a,b) and quality (Stobbs 1971,75) limitations.

Henzel and Stirk (1963) concluded that nitrogen, rather than rainfall, was the major limitation to grass production in sub-tropical Queensland. Linear responses to increasing rates of nitrogen have been reported under a range of climatic environments and on a range of soil types (Henzell 1963; Gartner 1969; Colman 1970; t’Mannetje and Shaw 1972; Scateni 1972, Cook 1984). Nitrogen was shown to change the growth patterns of tropical grasses (Cook 1984), but increased growth rates at all times of the year.
The management implications of using nitrogen fertilizer to increase late summer production by grasses for improved autumn grazing were seen as a means of improving the quantity and quality of feed during the period of greatest restriction. Significant milk production increases were demonstrated in north Queensland from the use of nitrogen fertilizer (Cowan and Stobbs 1976; Chopping et al 1978; Davison and Cowan 1978). The adoption of this technology was limited by the lack of information as to the impact of inputs of nitrogen fertilizer on the established farm feed production system, and the uncertainty of the response under lower rainfall conditions.

In an attempt to address these perceived limitations, an experiment was designed to investigate milk production responses to nitrogen applied on raingrown grass pastures in south-east Queensland. This work was undertaken on 12 commercial dairy farms to enable the response to be measured under a range of environmental conditions and in a commercial situation. Diversity of sites was envisaged as a major strength of the project in interpreting the response under a range of climatic conditions and soil types. It also gave increased opportunities in the identification of non-responsive or problem situations which might be expected to occur when this technology was adopted on a large number of farms.

This paper presents some of the unexpected animal performance limiting factors which have become evident during the 4 years of the experiment.

MATERIALS AND METHODS

The design chosen for the experiment was a multi-period incomplete block crossover as described by Bodero and Reason (1985).

On each of the 12 farms, a pasture area of 0.25 ha per cow was allocated to the experiment as the night grazing area for the herd. This area was fenced into four equal sized paddocks. Nitrogen treatments were allocated to pairs (six) of farms, and within each pair the paddock treatments were allocated so that one farm grazed in a H-L rotation, while the other grazed L-H treatment paddocks.

The nitrogen treatments under investigation were based on 50, 100 or 150 kg N per cow, giving pasture application rates of 200, 400 or 600 kg N per ha per year.

Cows in herds where abnormal herd/animal health conditions were exhibited were bled and samples submitted for routine metabolic profile analysis. In several herds, bleeding of a group of monitor animals was undertaken every three months. In assessing the sodium and potassium status of the animals, parotid saliva samples were taken as per the methodology of Murphy and Connell (1970). Plant chemical analyses were determined at regular intervals throughout the year, with more intensive sampling as required. Soil nutrient status was also assessed regularly.

Specific animal production problems which evolved during this experiment related to bloat, infertility and a general run-down of animal nutrient reserves.

PROBLEM CONDITION

Bloat

On two farms where kikuyu (Pennisetum clandestinum) was the dominant pasture species, bloat was reported as a mild to severe occurrence. Both farms were located in areas of volcanic (basalt) parent material, the majority of the farm being a Krasnozem (Stace et al 1978) soil with a principal profile form Gn 3.11 (Northcote 1979). Cows on these farms exhibited low sodium, and low Na:K ratios in parotid saliva, (Murphy and Connell 1970, Murphy and Plasto 1973) indicating that animals were sodium deficient. On one farm, mean saliva
potassium level was 11.6 m.mol/L (range 6.8-23.4) the Na:K ratio varied from 3.8:1 to 20.8:1. Chemical composition of water supplies drawn from wells and bores are given in Table 1.

Table 1  Chemical composition (mg/L) of water supplies (wells and bores) used on farms where bloat problems were experienced

<table>
<thead>
<tr>
<th>Component</th>
<th>Concentration mg/L</th>
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<tbody>
<tr>
<td>Cations</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td>36</td>
</tr>
<tr>
<td>Magnesium</td>
<td>77</td>
</tr>
<tr>
<td>Sodium</td>
<td>403</td>
</tr>
<tr>
<td>Potassium</td>
<td>3</td>
</tr>
<tr>
<td>Anions</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate</td>
<td>202</td>
</tr>
<tr>
<td>Sulphate</td>
<td>24</td>
</tr>
<tr>
<td>Chloride</td>
<td>583</td>
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</table>

It was observed that the bloat occurred shortly after the cows drink at a water trough and may be explained through the following sequence of events:

1. Cows are grazing nitrogen fertilized pasture which is growing vigorously. Supplies of soluble carbohydrate are enhanced as a result of grazing these fertilized pastures, and lead to acid fermentation patterns in the rumen. Kikuyu is a known poor sodium accumulator and observed values in this study varied from 135 to 260 mg/kg plant dry matter.

2. The normal drinking pattern of the cows is disrupted by an activity such as mustering for milking. The source of water supply is also critical, as bloat occurs when the water supply is drawn from aquifers on basalt parent material. These waters are relatively high in bicarbonates (Table 1) as a result of this close association with the basalt deposits. After the drinking pattern is disrupted, a larger volume of water is consumed at the next opportunity.

3. Cows with low sodium reserves (Na:K ratios as low as 3.8:1) may have difficulty in maintaining 'normal' rumen pH levels due to acid fermentation patterns in the rumen. Sodium plays an essential role in buffering rumen pH during digestion, and aiding the transport of V.F.A.'s produced during digestion through the gut wall. Cows may have an accelerated VFA production rate due to rapid fermentation of soluble carbohydrate in the rumen, and failure of these sodium dependent buffering and transport systems leads to the development of very acid conditions in the rumen.

4. Cows drink a larger than usual volume of water at the first opportunity after drinking is interrupted, e.g. due to mustering, and this leads to the release of significant amounts of carbon dioxide from the bicarbonate intake and the subsequent rapid onset of bloat conditions.

This sequence of events is supported by the discovery of most affected animals within 50 metres of a water trough, and an onset to death period of less than 10 minutes. Cows which did not exhibit traditional bloat symptoms were observed to be 'tight' in the flank and show sub-clinical bloat.

The introduction of sodium supplementation resulted in a decrease in bloat incidence from six deaths in 2 months to no death in 2 1/2 years.
Cow Reproductive Problems

On one farm, approximately 12 months after the introduction of nitrogen fertilizer, first service conception rate declined from 60% to 18% over a 3-4 month period. Cows were tested for a number of diseases affecting fertility but no causal agents were identified. Cows were being diagnosed pregnant by rectal palpation at 42-60 days post insemination, but they would then recycle at 70-120 days after insemination.

Symptoms were consistent with previous reports of phosphorus deficiency, though cows were receiving 50 gms/day of monoammonium phosphate (MAP) or 11 gms P per day. Nitrate toxicity was also suggested as a possible cause. Nitrate levels varied from not detected to 430 ppm on pastures fertilized at 600 kg N/ha/year, and from not detected to 390 ppm on pastures fertilized at 200 kg N/ha/year. The pasture species was Kikuyu (Pennisetum clandestinum), and samples were taken in the early morning (6.00 a.m.) to measure maximum levels. There was no consistent trend in plant nitrate levels due to level of applied nitrogen, or time since last nitrogen (urea) application.

Pasture samples (plucked leaf) were taken each week and analysed for nitrogen, phosphorus and calcium. The results are reported in Table 2.

Table 2  Mean values and standard deviations for plant nitrogen, phosphorus and calcium levels, and Calcium/Phosphorus ration in plucked leaf samples of kikuyu fertilized at 200 or 600 kg N/ha/year.

<table>
<thead>
<tr>
<th>Nitrogen Level</th>
<th>Nitrogen (%) Mean</th>
<th>SD</th>
<th>Phosphorus (%) Mean</th>
<th>SD</th>
<th>Calcium (%) Mean</th>
<th>SD</th>
<th>Ca/P Ratio Mean</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>200 kg N/ha/yr</td>
<td>3.06 0.80</td>
<td></td>
<td>0.32 0.061</td>
<td></td>
<td>0.31 0.035</td>
<td></td>
<td>1.039 0.37</td>
<td></td>
</tr>
<tr>
<td>600 kg N/ha/yr</td>
<td>3.23 0.21</td>
<td></td>
<td>0.32 0.044</td>
<td></td>
<td>0.29 0.030</td>
<td></td>
<td>0.907 0.14</td>
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</tbody>
</table>

Plant calcium levels were lower than accepted dietary levels for high producing dairy cows. The availability of calcium in the plant material may also have been adversely affected by the high potassium levels (up to 5.0%) in the plant material. Plant K levels were found to increase with increasing nitrogen levels in the plant material (Reason - unpublished data).

Blaney et al (1981) also reported moderate to high oxalate levels in samples of kikuyu analysed at the Animal Research Institute. In this study, oxalate levels of up to 1.9% oxalic acid in the dry matter were recorded. These levels would be expected to severely affect the availability of the calcium in the plant material.

It was therefore suggested that the apparent phosphorus deficiency symptoms observed while supplements of P (as MAP) were being fed could be attributed to low P absorption as a consequence of low calcium availability (Manston 1967).

Cows were therefore supplemented with Dicalcium phosphate (DCP) at an initial rate of 100 gms/day, and reproductive performance returned to acceptable levels (60% first service conception rate) within 6 weeks. Subsequent events showed that, after rainfall, pasture growth rates were accelerated and some minor interruption to reproductive performance occurred for 3-4 months. It is assumed that these perturbations were due to reduced calcium availability through either dilution of calcium in the rapidly growing plant material, a rapid increase in oxalate as high nitrogen content leaf growth occurs, or a combination of both of these factors.
Metabolic Profiles Over Time

In one herd, a monitor group of 20 animals has been bled each 3 months since early 1985. These cows have rotationally grazed setaria/green panic/kikuyu pastures fertilized at 400 or 600 kg N/ha/year every night since November 1984.

Mean annual results of these metabolic profile analyses, which show no significant effects due to changes in stage of lactation, are presented in Table 3.

Table 3 Mean annual values for blood metabolites for cows grazing heavily fertilized grass pastures

<table>
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</thead>
<tbody>
<tr>
<td>Calcium mM/L</td>
<td>2.42</td>
<td>2.24</td>
<td>2.32</td>
<td>2.07</td>
<td></td>
</tr>
<tr>
<td>Magnesium mM/L</td>
<td>1.11</td>
<td>1.03</td>
<td>1.04</td>
<td>1.10</td>
<td></td>
</tr>
<tr>
<td>Phosphorus mM/L</td>
<td>1.52</td>
<td>1.55</td>
<td>1.60</td>
<td>0.77</td>
<td></td>
</tr>
<tr>
<td>Copper ug/L</td>
<td>754</td>
<td>703.5</td>
<td>660</td>
<td>692</td>
<td></td>
</tr>
<tr>
<td>Zinc ug/L</td>
<td>1052</td>
<td>935.7</td>
<td>972.5</td>
<td>894.1</td>
<td></td>
</tr>
<tr>
<td>GSHpx IU/gHb</td>
<td>64.9</td>
<td>75.3</td>
<td>45.1</td>
<td>46.5</td>
<td></td>
</tr>
<tr>
<td>Glucose mM/L</td>
<td>4.22</td>
<td>3.72</td>
<td>3.41</td>
<td>2.13</td>
<td></td>
</tr>
<tr>
<td>Total Protein g/L</td>
<td>74.78</td>
<td>77.10</td>
<td>82.47</td>
<td>73.84</td>
<td></td>
</tr>
<tr>
<td>Albumin g/L</td>
<td>34.32</td>
<td>33.30</td>
<td>34.56</td>
<td>31.53</td>
<td></td>
</tr>
<tr>
<td>Globulin g/L</td>
<td>40.43</td>
<td>43.79</td>
<td>47.91</td>
<td>42.31</td>
<td></td>
</tr>
<tr>
<td>A/G ratio</td>
<td>0.857</td>
<td>0.785</td>
<td>0.735</td>
<td>0.752</td>
<td></td>
</tr>
</tbody>
</table>

These results indicate a trend towards lower serum calcium, phosphorus, zinc, glucose and albumin levels over this period. After an initial decline, blood magnesium levels returned to near 1985 levels in 1988 – probably in response to the lowered calcium levels. The copper levels in 1988 were variable, and the higher standard error of the estimates of mean Cu levels resulted in a non-significant effect on blood Cu in 1988.

Pasture dry matter yields (kg DM/ha) in summer each year were 1985 - 1400, 1986 - 3 600, 1987 - 4 300 and 1988 - 600 for pastures fertilized at 400 kg N per ha and 2 100, 5 500, 6 500 and 650 for the 1985-88 years respectively on the 600 kg N per ha fertilized paddocks. These results illustrate the severe depression in pasture yields in early 1988 which had a significant impact on parameters such as blood glucose at that time.

DISCUSSION

The impact of inputs of nitrogen fertilizer to the established farm feed production system on a number of commercial dairy farms can be readily measured in terms of increased milk production, increased animal liveweights, improved reproductive performance, more vigorous pasture with improved botanical composition through higher frequencies of the more desirable species of grasses and reduced frequencies of weeds, and improved financial position of the farm.

These criteria do not always measure – unless some catastrophic event occurs - the subtle changes in animal requirements as supplementary feeds (principally - grain and/or molasses) are replaced by paddock feed. Paddock feed is generally considered to be the cheapest basal ration for dairy cattle in Australia, and one result of increased use of nitrogen fertilizer on these trial farms has been to reduce grain/concentrate inputs per cow to 70% of 1983-84 levels, while supporting higher levels of per cow and per ha production.
These grain/concentrate feeds do however provide more than just energy, and under some circumstances the longer term effects of their withdrawal may be the reduction of body reserves of essential minerals to the extent that deficiencies become apparent through production ceilings on reproductive pastures. These changes may also be aggravated by reduced availability of minerals in paddock feed due to interference in absorption by high nitrogen levels (e.g. Cu), the parallel rise in oxalate or other binding agents (e.g. Ca) or the dilution of nutrients through rapid accumulation of pasture dry matter. Some of the improved grasses may be poor nutrient accumulators e.g. low sodium in kikuyu and/or low phosphorus in Rhodes grass (Reason - unpublished data). Increased milk production levels also increase the demand on milking cows to recycle nutrients at an ever increasing rate. Most work to date with milking cows in northern Australia has concentrated on improving the quantity and quality (Stobbs 1971, 1975) of feed on offer to the cow - based on the premise that energy and protein are the major factors limiting production. As per cow production and per ha production increase, particularly through the adoption of fertilized pasture with strategic supplementation with concentrates as the productive base, we are more likely to move into those situations where nutritional limitations to production are due to factors other than shortage of energy or protein in the diet.

In this study, production levels of 5,000 to 6,000 litres of milk per ha from paddock feed (net of supplementary feed inputs) have been achieved on 3 of the 12 farms. Under these conditions, mineral nutrients are likely to play an increasingly important role in limiting further production gains to energy and/or protein supplementation.

REFERENCES


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