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The effect of applying cattle slurry as the sole source of nutrients over a four year period on the yield and persistency of seven perennial forage crops

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OVERALL SUMMARY OF EXPERIMENT

- As fertiliser becomes more expensive, farmers should seek to make more efficient use of nutrients contained within slurry and manures. However, relatively little is known about the short and long term responses of different forage types to repeated applications of slurry, especially when applied as the sole source of nutrients.
- To address this issue seven different forage species were sown at Hillsborough in August 2004. These were as follows:

  Diploid ryegrass
  Tetraploid ryegrass
  Hybrid ryegrass
  Italian ryegrass
  Low input mix
  Ryegrass and white clover mix
  Red clover
- Once established, each forage species was treated with one of four levels of slurry (0, 34, 60 and 89 m^3/ha/year: 0, 3000, 5300, and 7900 gallons/acre/year), with herbage harvested 3 or 4 times per year. No inorganic (bag) fertiliser was applied throughout the duration of the four year experiment.
- At the highest level of slurry application, the diploid and tetraploid ryegrasses produced approximately 12 t DM/ha/year, the hybrid ryegrass, low input mix and the grass/clover mix approximately 13.5 t DM/ha, while the red clover and Italian ryegrass produced in excess of 14 t DM/ha/year over the four years of the experiment.
- Although annual yields of all forages were in excess of 12.8 t DM/ha/year in Years 1 and 2, yields declined considerably in Years 3 and 4. This decline in yield is likely the result of a depletion of soil mineral nitrogen reserves, with the yields achieved in Years 3 and 4 likely to provide a true reflection of the yield potential of slurry as the sole source of nutrients.
- Level of slurry application had no effect on the percentage of sown species remaining in the plots at the end of Year 4. This demonstrates that the persistence of these forages was not disadvantaged by repeated applications of slurry. The Italian ryegrass contained the highest proportion of sown species in Year 4 (97%), with the red clover containing the lowest (69%).
- When no slurry was applied, the red clover produced the highest average annual yield (13.8 t DM/ha), with the grass/clover the next highest (11.3 t DM/ha). Red clover consistently achieved the highest annual yield when no slurry was applied.
- As annual slurry application rate increased the yield responses of the forages to slurry nitrogen decreased, declining from 21 kg DM/kg N when 34 m^3/ha were applied to approximately 14 kg DM/kg N when 89 m^3/ha were applied.

- The clover forages had a lower response to slurry nitrogen than the grass-only forages. The amount of atmospheric nitrogen fixed by the clover swards decreased with the application of slurry.
- Soil pH increased with increasing slurry application rate. Clover swards had a consistently lower soil pH (more acidic) than the grass swards.
- Soil phosphorus levels were index 4 at the start of the experiment and did not decrease with the low slurry application treatment. This highlights that when soil phosphate reserves are high (index 4), reserves decrease slowly.
- Soil potassium content decreased rapidly when no slurry was applied, however it remained relatively constant with the two highest slurry application rates (60 and 89 m^3/ha). This demonstrates that slurry nutrients alone can sustain soil potassium levels for swards under a continuous cutting management regime.

BACKGROUND

Dairy cow slurry is a rich source of nutrients for plant growth. For example, one tonne (220 gallons) of dairy cow slurry with a dry matter content of 6% contains approximately 3.0 kg of nitrogen, 1.2 kg of phosphate and 3.5 kg of potash. However, as the cost of inorganic (bag) fertiliser looks set to increase in the future, farmers must increasingly make more effective use of the nutrients contained in slurry and manures. This is especially true in view of the very significant investments in slurry storage facilities that have been made on many farms in recent years. Having invested in manure storage, it makes sense to recoup some of this outlay by maximising the benefit that can be achieved from the nutrients contained in manures.

While previous research has shown that different grass species vary in their yield response to inorganic fertiliser nitrogen, less is known about the yield response of different species to slurry nitrogen. Furthermore, the long term effects on forage yield and longevity of repeated applications of slurry as the sole source of nutrients have not been fully tested. This may become increasingly important in the future as farms seek to increase their reliance on slurry nutrients, and reduce their usage of expensive bag fertilisers. Thus there is a need to identify the production responses of a range of forages to repeated applications of slurry. In addition, it is important to identify optimum slurry application rates which are not detrimental to the longevity of forages or which result in nutrient imbalances within the soil.

Objective of this experiment

To examine the effect of four slurry application rates, when applied as the sole source of nutrients over a four year period, on the yield and persistency of seven perennial forages, and on soil nutrient status.

TREATMENTS EXAMINED AND MEASUREMENTS TAKEN

Establishment of experimental forages:

This experiment was conducted at AFBI Hillsborough on a site with an initial soil phosphate index of 4 and a potassium index of 2-. The site received 20 m^3/ha of cattle slurry before being ploughed and conventionally cultivated. The seven experimental forages were sown during August 2004 in plots measuring 1.5 m wide and 6.0 m long. Details of the cultivars sown and the corresponding seed rates are presented in Table 1. These comprised four ryegrass forages (diploid, tetraploid, hybrid and Italian) and a mixture of four grass species (ryegrass, cocksfoot, meadow fescue and timothy). The latter was described as a 'low input mix' as it was specifically designed for farming systems with reduced nutrient inputs. Two additional treatments contained forage legumes, namely a perennial ryegrass/white clover mix and a pure crop of red clover. In total, 16 plots of each forage were established within this experiment.

Table 1. Forages sown within the experiment and their seed rates.

Forage	Seed rate (kg/ha)	Cultivars
Diploid ryegrass[1]	22	Pastour, Gilford
Tetraploid ryegrass[1]	33	Navan, Greengold
Hybrid ryegrass[1]	33	Aberlinnet, Belleek
Italian ryegrass[1]	40	Meribel, Ligrande
Low input mix	33	Ryegrass - Navan (20%) Cocksfoot - Barmoral (20%) Meadow Fescue - Pradel (30%) Timothy - Comer (30%)
Ryegrass and white clover mix	34	Ryegrass[1] - Gilford, Navan Clover [2]
Red clover	12	Merviot

[1] Cultivars mixed 50:50

[2] 4 kg/ha (cultivars Crusader (50%), Alice (25%), Barblanca (25%))

Slurry management:
No inorganic (bag) fertiliser was applied throughout the duration of the experiment. Each of the forages described above was treated with slurry at one of four application rates, namely 0, 34, 60 and 89 m^3/ha per year (0, 3000, 5300 and 7900 gallons/acre/year). With each slurry application rate, approximately half of the total annual slurry application was applied in spring, while 25% was applied after each of the first and second harvests. All slurry was applied using the trailing-shoe technique, with four plots of each forage treated with each slurry application rate. Low emission slurry spreading techniques such as the trailing-shoe systems have been shown to improve nutrient use efficiency in comparison to splash plate spreading. For example, grass yields have been shown to be increased by 20% when slurry is applied with a trailing-shoe compared to a splash plate system, with this largely due to an improvement in the efficiency of nitrogen use.

Harvesting and soil sampling:
The experiment was conducted over four successive growing seasons (2005 – 2008), with the forages harvested on three occasions during Years 1, 2 and 4 and on four occasions during Year 3 (Table 2). The yield of forage was recorded at each harvest and samples taken to determine the dry matter content of the herbage. In addition, a sample was taken to assess the percentage of sown species remaining in each plot at each harvest. This was done by identifying the weight of sown species in the sample after removing the weeds and unsown species. Slurry applied on each occasion was analysed for nitrogen content. Soil samples were taken from all plots to a depth of 7.5 cm at the end of each year of the experiment.

Table 2. Dates on which forages were harvested throughout the four years of the experiment.

Harvest	Year 1	Year 2	Year 3	Year 4
First	07 June	30 May	14 May	15 May
Second	26 July	19 July	26 June	04 July
Third	27 September	04 October	23 August	22 August
Fourth			04 October	

Response to nitrogen:
The response of each forage to slurry nitrogen was calculated as the difference between the yield of forage achieved following the application of slurry and the yield achieved when no slurry was applied, divided by the quantity of slurry nitrogen applied.

OUTCOMES OF THE EXPERIMENT

Annual dry matter yield with each of the seven forages

- Annual dry matter yields of each of the seven forages (mean of the four years) are presented in Figure 1 for the highest slurry application treatment (89 m^3/ha). This is a slurry application rate that would be typical of that used on many farms during the course of a year.
- On average, across the four years of the experiment, the diploid and tetraploid ryegrasses produced approximately 12 t DM/ha/year, the hybrid ryegrass, low input mix and the grass/clover mix approximately 13.5 t DM/ha and the red clover and Italian ryegrass swards in excess of 14 t DM/ha.
- The lower yields of the diploid and tetraploid ryegrasses are not surprising as these are generally considered lower yielding. The intermediate yields of the low input mix are due to the inclusion of a high yielding cocksfoot variety, and the yield benefit associated with a mixture of grass varieties being sown together.
- The highest annual yields achieved within any one year were 17.9 t DM/ha for red clover (Year 1), 17.4 t DM/ha for the low input mix (Year 2) and 17.1 t DM/ha for the hybrid ryegrass (Year 2).

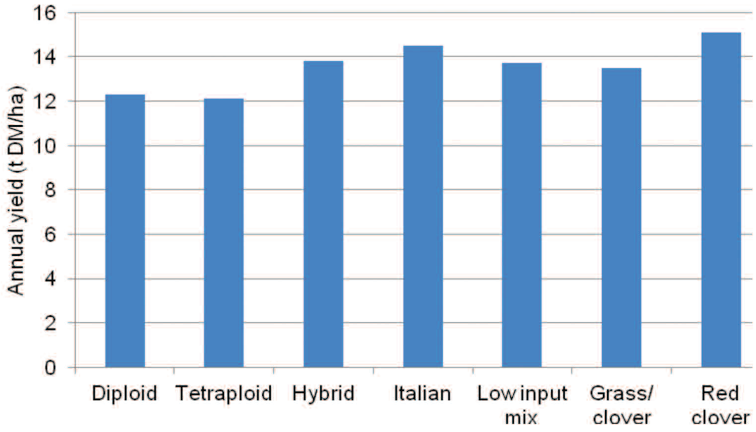

Figure 1. Annual yields of each of the forages averaged across the four years of the experiment (89 m^3/ha slurry treatment).

Change in yield of dry matter produced over time

- Changes in the annual yield of each of the forages across the four years of the experiment are presented in Figure 2 for the 89 m^3/ha slurry application treatment.
- Annual yields were in excess of 12.8 t DM/ha for all forages in Years 1 and 2, but yields decreased in Years 3 and 4. For example, the average annual dry matter yield of the tetraploid, low input mix and red clover forages was approximately 30% lower in Years 3 and 4 than in Years 1 and 2, while the yield of the grass/clover mix and Italian ryegrass forages dropped by approximately 20% in Years 3 and 4, compared to Years 1 and 2.
- GrassCheck data from Hillsborough provided no evidence that grass growing conditions in Years 3 and 4 were markedly different to those in Years 1 and 2. Thus, the higher yields in Years 1 and 2 are likely to be largely due to soil mineral nitrogen reserves becoming available following ploughing at crop establishment. These reserves will have been largely depleted by Years 3 and 4, and as such the crop yields measured at this stage are likely to provide a true reflection of the yield potential of slurry as the sole source of nutrients.
- While yields were not measured after Year 4, it is expected that yields would have stabilised thereafter. Evidence to support this suggestion is provided by an earlier study at Hillsborough (involving a slurry application rate of 100 m^3/ha/year: 8900 gallons/acre/year), in which an average dry matter yield of 12.2 t DM/ha/year was achieved from the application of cattle slurry alone over 15 consecutive years.

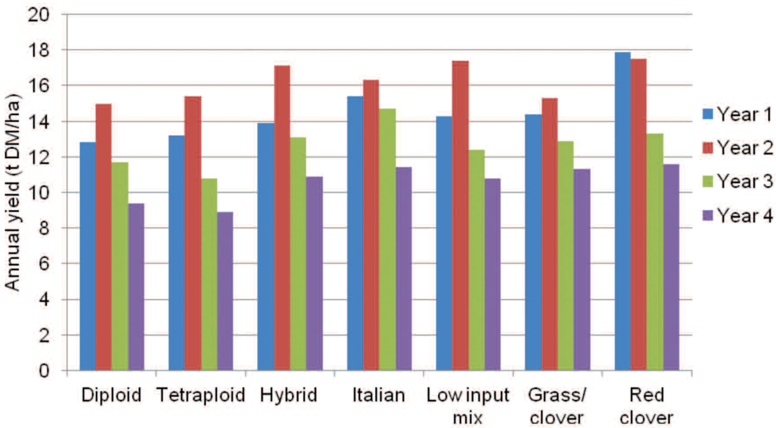

Figure 2. Annual yield of herbage produced (tonnes dry matter per hectare) by each of the seven forages over the four years of the experiment within the 89 m^3/ha slurry treatment.

Persistency of each of the seven forages, and herbage composition

- The decline in the percentage of each of the 'sown species' within the plots during the four years of the experiment are presented in Table 3. While the percentage of red clover in the swards had declined to 69% by Year 4, the proportion of sown species for all other forages remained high, with the Italian ryegrass in particular retaining a high proportion of sown species (more than 97%) throughout the experiment. Given that Italian ryegrass and red clover are generally considered short-term leys (2 or 3 years), the level of sown species recorded in Year 4 was good.
- The rate of slurry applied had no effect on the proportion of sown species present in any of the swards throughout the four year period. This demonstrates that the persistence of these crops was not disadvantaged by the application of slurry with the trailing-shoe over the four years of the experiment.
- The average crude protein content of the clover forages over the four years was between 14 and 16%, considerably higher than for the grass-only forages. The crude protein content of the forages was not affected by slurry application rate.

Table 3. Changes in the percentage of herbage harvested that comprised the sown species' during the four years of the experiment.

	Diploid ryegrass	Tetraploid ryegrass	Hybrid ryegrass	Italian ryegrass (% of dry matter)	Low input mix	Grass/ clover	Red clover
Year 1	91	96	98	100	92	96	80
Year 2	98	98	99	100	99	99	89
Year 3	95	96	97	99	99	96	78
Year 4	85	91	92	97	97	94	69

Annual dry matter yield response to slurry nutrients

- When no slurry was applied, red clover achieved the highest average annual yield over the four years (13.8 t DM/ha), followed by the grass/clover sward (11.3 t DM/ha). This highlights the ability of these two legume crops to fix their own nitrogen (Figure 3).
- Italian ryegrass was the highest yielding grass-only forage when no slurry was applied, producing 10.4 t DM/ha on average over the duration of the experiment. The diploid and tetraploid swards were the lowest yielding when no slurry was applied (7.3 and 7.4 t DM/ha, respectively).
- In general, when no slurry was applied there was a trend for the yield of most forages to decline after Year 2, as presented in Figure 3. This reflects soil nitrogen reserves becoming exhausted. For example, the average annual yield achieved by the diploid ryegrass fell from 8.4 t DM/ha in Year 1 to 4.7 t DM/ha in Year 4.
- Surprisingly, the yields of the legume swards also decreased after Year 2. For red clover, this declining yield is likely to reflect the decreasing content of red clover in the sward by Year 4 (69%). However, reasons for the declining yields within the grass/clover sward are less clear, although it is possible that a depletion of soil potassium levels in the absence of applied nutrients could have been a contributing factor.

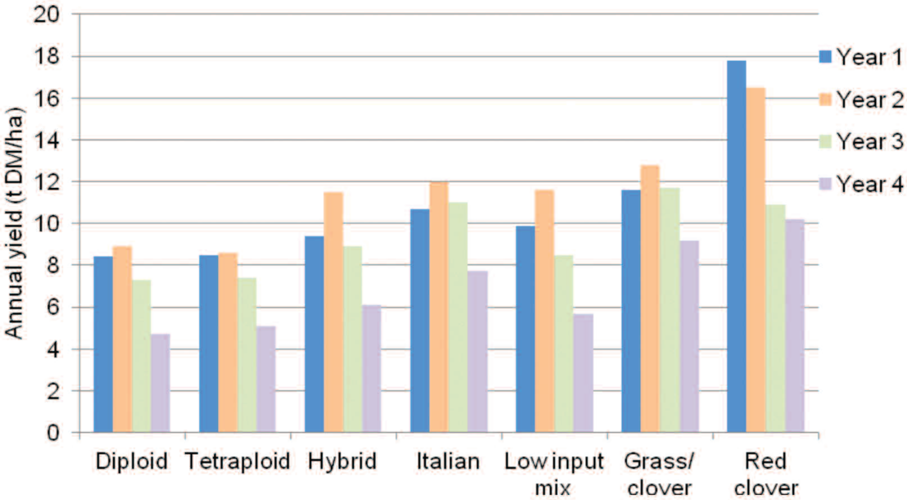

Figure 3. Declining annual yield of herbage (tonnes dry matter per hectare) when no slurry was applied over four years

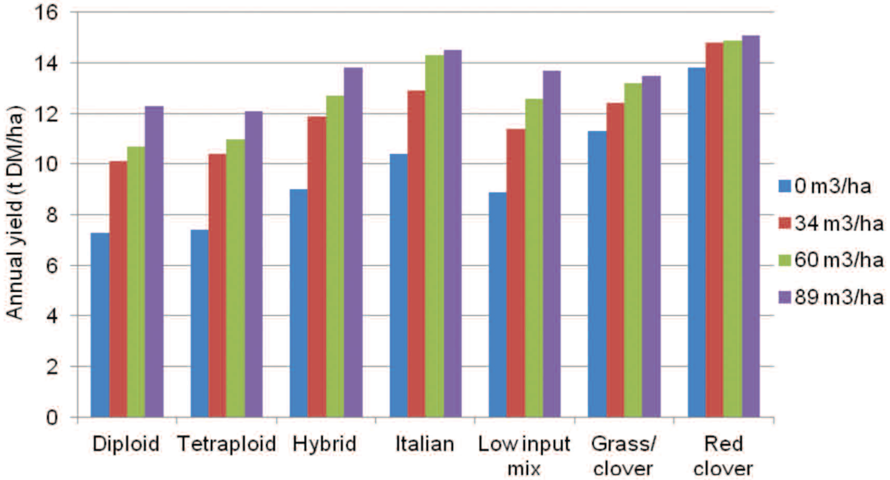

Figure 4. Annual herbage yield (tonnes dry matter per hectare) of each of the forages (mean for Years 1 – 4) when treated with either 0, 34, 60 or 89 m^3 slurry/ha.

- Figure 4 clearly highlights that the dry matter yield of each of the forages tended to increase with increasing slurry application rates, although the increase in yield tended to 'slow off' at the higher slurry levels. Across all species the average yield response was 21.1 kg DM/kg N when 34 m^3/ha was applied, 15.9 kg DM/kg N when 60 m^3/ha was applied, and 13.6 kg DM/kg N when 89 m^3/ha was applied.
- Figure 5 examines the mean response to slurry nitrogen (across all slurry levels) of each of the forages during the four years of the study. On average, the yield response of the four grasses was between 18 and 22 kg DM per kg slurry N. This clearly demonstrates the considerable value of slurry nitrogen.
- The red clover and grass/clover mix showed the poorest response to slurry N (Figure 5), and indeed yields did not increase when slurry was applied above 60 m^3/ha. These poor responses to slurry N reflect the potential of legumes to fix atmospheric N. Indeed, applied slurry reduced nitrogen fixation by the clover swards. It is estimated that when no slurry was applied, nitrogen fixation by the white clover and red clover contributed approximately 152 and 243 kg N/ha/annum, with this decreasing to approximately 93 and 164 kg N/ha/annum when 89 m^3/ha of slurry were applied.
- It should be noted that a lower yield response is likely to have been achieved if slurry had been applied using a splash plate rather than a trailing-shoe system. Previous research at Hillsborough has demonstrated lower efficiency of nitrogen utilisation with the splash plate technique, especially with slurry applications in June and July, when nitrogen losses can be particularly high.

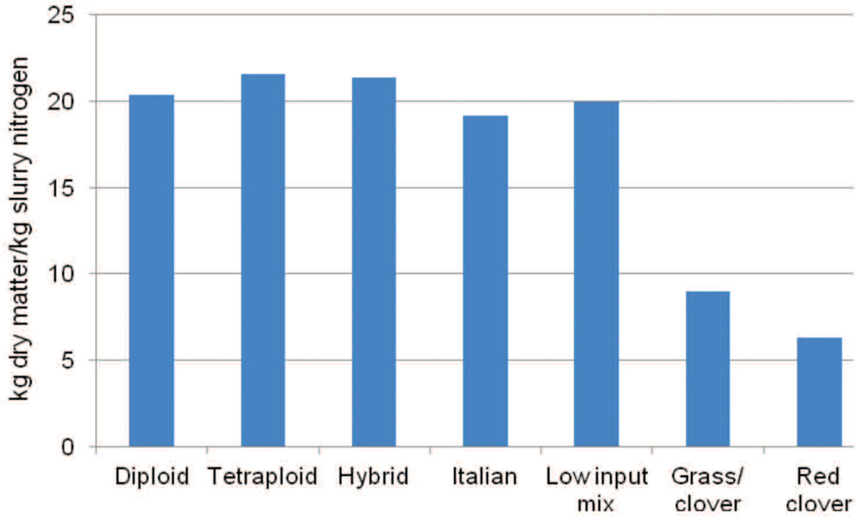

Figure 5. Average annual yield response (kg dry matter per kg slurry nitrogen) of each of the seven forages to slurry nitrogen across the four years of the experiment.

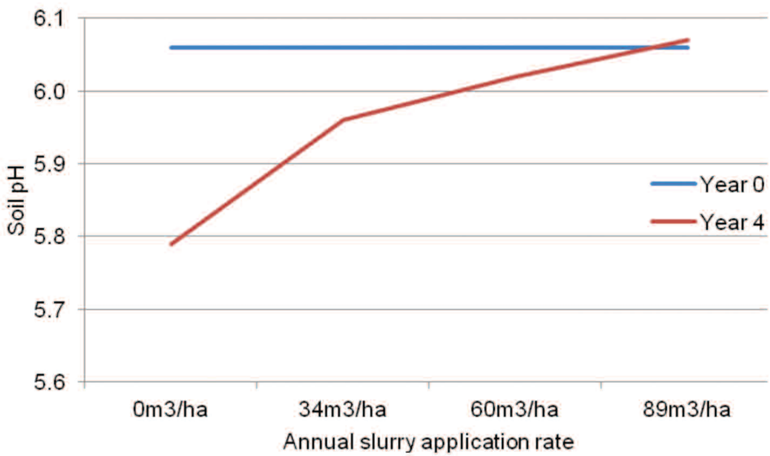

Figure 6. The effect of slurry application rate over a four year period on soil pH.

Effect of forage type and slurry application rate on soil pH and mineral status.

- Prior to the start of the experiment the average soil pH was 6.05, as shown in Figure 6. Over the course of the experiment soil pH decreased to 5.8 when no slurry was applied, while remaining relatively unchanged (6.1) within the 89 m^3/ha slurry application treatment.
- The soil pH of the clover swards was consistently lower than for all other forages (Figure 7). This acidifying effect is likely linked to the process of nitrogen fixation within the soil by the clovers.

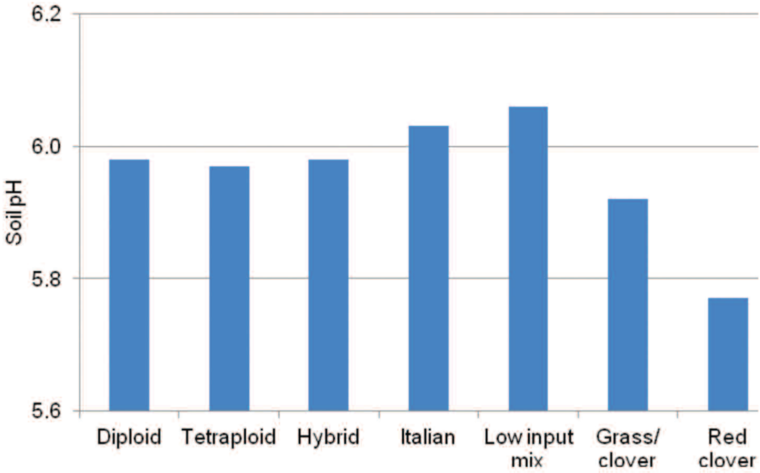

Figure 7. The effect of forage type on soil pH at the end of Year 4.

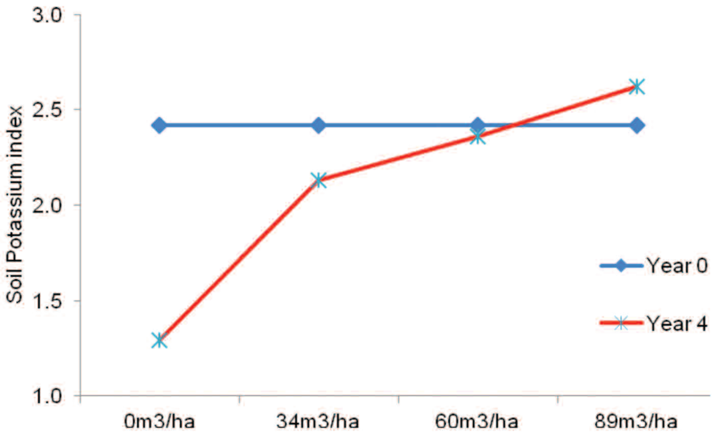

Figure 8. The effect of slurry application rate over a four year period on soil potassium content.

- Figure 8 clearly shows that soil potassium content fell over the four year period when no slurry was applied, but remained relatively constant with the 60 m^3/ha and 89 m^3/ha slurry treatments. This highlights that at these higher slurry application rates, slurry alone can maintain soil potassium reserves for swards under a management regime involving 3 or 4 harvests per year.
- At the start of the study the soil had a phosphorus (P) index of 4.0. However, soil P index did not change during the course of the experiment. This highlights that when soil P reserves are high, reserves decrease slowly, even when no slurry nutrients are applied.
- Soil P levels were consistently higher with the red clover swards. The reasons for this are unclear, given that red clover tends to have a higher requirement for P than grasses.
- Soil magnesium and soil sulphur content generally increased with the application of slurry within this experiment.

CONCLUSIONS

Slurry as the sole source of nutrients (89 m^3/ha/year) was able to sustain long term yields (4 years) of between 8.9 and 11.6 t DM/ha across the range of forages examined, while maintaining soil nutrient status. When no nutrients were supplied, grass/clover swards and red clover swards were able to sustain long term yields (4 years) in excess of 9.2 t DM/ha due to fixation of atmospheric nitrogen.

ACKNOWLEDGEMENTS

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