THE EFFECT OF STORAGE AND RAPID INCORPORATION ON N_2O EMISSIONS FOLLOWING THE APPLICATION OF PIG AND CATTLE FYM TO LAND

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ABSTRACT

Following the application of solid manure to arable land, rapid incorporation has been recognised as a successful technique to reduce ammonia emissions. There is, however, the potential for nitrous oxide (N_2O) emissions to increase. FYM was generated from groups of pigs and cattle using conventional amounts of straw or additional straw in the buildings. Emissions of N_2O were monitored at 2 sites; a loamy sand soil in central England (ADAS Gleadthorpe) and a coarse sandy loam soil in south west England (IGER North Wyke). Emissions were measured following a target application of 250 kg N ha^{-1} of either pig (ADAS) or cattle (IGER) FYM. The FYM was spread fresh (pig only) or had been stored for 12 months. The manure was then either left on the surface, incorporated within 4 hours using a disc (IGER only) or plough. No consistent effect of incorporation on N_2O emissions was evident. Ploughed, fresh pig FYM resulted in significantly ($P < 0.001$) larger emissions when expressed as a % of N applied lost as N_2O. The ploughed stored treatments also emitted more N_2O than from the surface treatments, although this was not significant. Following the application of cattle FYM there was no significant ($P > 0.05$) effect of storage conditions or incorporation technique. The results do, however indicate that cattle FYM left on the soil surface resulted in greater N_2O emissions than from the incorporation techniques. The % of total N applied lost as N_2O was small (generally < 0.20 %) probably as a result of the low NH_4-N content of the stored manure, suggesting that storage may be used as a technique to reduce N_2O emissions.

INTRODUCTION

Around 46 million tonnes of the animal manure in the UK is in a solid form and is frequently stored before spreading onto land. Following the application of solid manures to arable land, rapid incorporation has been identified as an effective measure to abate ammonia (NH_3) emissions. The reduced NH_3 loss, however, conserves nitrogen which may subsequently be used in the production of nitrous oxide (N_2O). The UK has agreed to reductions in greenhouse gas emissions of 12.5 % of 1990 levels by 2008-12. It is, therefore, important that measures implemented to reduce NH_3 emissions do not result in the increased loss of N_2O. The objectives of this Defra funded study are to quantify and compare N_2O emissions from fresh and stored pig farmyard manure (FYM) and stored cattle FYM following land spreading and to quantify the effect of rapid incorporation.

MATERIALS AND METHODS

FYM was produced from groups of pigs and cattle using conventional amounts of straw (conventional) or additional straw (straw) in buildings. Pig FYM was spread on a loamy sand soil at ADAS Gleadthorpe in central England and cattle FYM was spread on a coarse sandy loam soil at IGER North Wyke in south west England. At ADAS the pig FYM was spread to cereal stubble, whilst at IGER the cattle FYM was applied to bare ground. Both pig and cattle FYM were applied at a target application rate of 250 kg N ha^{-1} to replicated (x 3) plots (ADAS:12 m by 4 m, IGER:6 m by 3 m). Pig FYM, fresh or stored for 12 months, was spread in late March 2003 and either left on the surface or ploughed within 4 hours. Cattle FYM that had been stored for 12 months was spread in July 2003, and either left on the soil surface or incorporated within 4 hours by either plough or disc. Additionally, control treatments were included where no manure was added.

Following manure application, measurements of N_2O were made over a 52 d (IGER) or 94 d (ADAS) period using static chambers (0.4m x 0.4m x 0.3m, 2 per plot). Analysis of headspace samples was made by photo-acoustic infra-red spectroscopy (ADAS) or gas chromatography (IGER).

RESULTS AND DISCUSSION

Following the application of pig FYM N_2O emissions measured from the control and from all 3 of the surface spread treatments were consistently < 5 g N_2O-N ha^{-1} d^{-1}. Peak emissions measured from the ploughed treatments were, however, up to 19 times larger and followed the order; stored with added straw (8 g N_2O-N ha^{-1} d^{-1}) < conventionally stored (16 g N_2O-N ha^{-1} d^{-1}) < fresh (95 g N_2O-N ha^{-1} d^{-1}). This pattern was reflected in the % of N applied lost as N_2O, although only one significant difference between treatment means was observed. The % loss from the ploughed, fresh pig FYM treatment was significantly greater ($P < 0.001$) than from all other treatments (Fig 1).

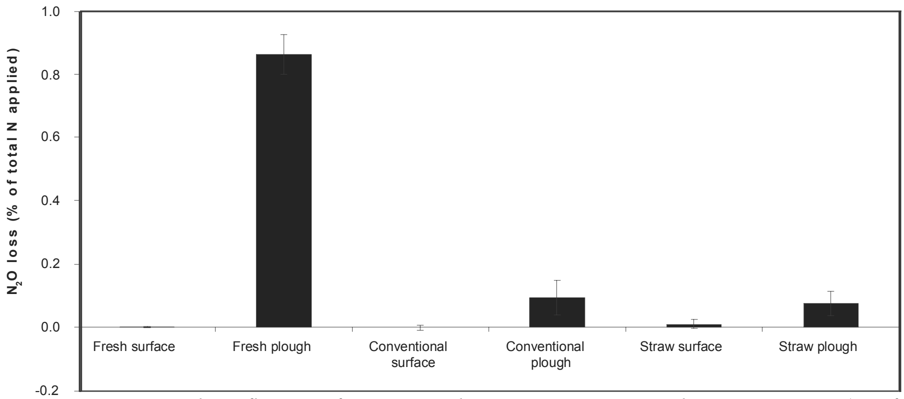

Figure 1*. The influence of storage and incorporation on total N_2O emissions (% of total N applied) following pig FYM applications.*

The greater N_2O emission from the ploughed treatments was probably a reflection of the lower NH_3 loss increasing the soil mineral N pool potentially available to nitrifying and denitrifying micro-organisms. Indeed at the same site in the previous spring, *c*. 34% of the applied readily available N was lost as NH_3 from the fresh surface treatment, whereas only *c*. 8% was lost from the fresh ploughed treatment.

The application of fresh pig manure is likely to have stimulated N_2O emissions due to its higher NH_4-N content (*c*. 1.7 kg t^{-1}) compared to that in the stored manures (*c*. 0.1 kg t^{-1}). The difference in TAN content was the result of loss of the readily available N content during storage. Indeed, when cumulative emissions were expressed as a % of total NH_4-N (TAN) applied there was no significant difference ($P > 0.05$) between manure types, with values ranging from 0 to 10%. (Fig 2).

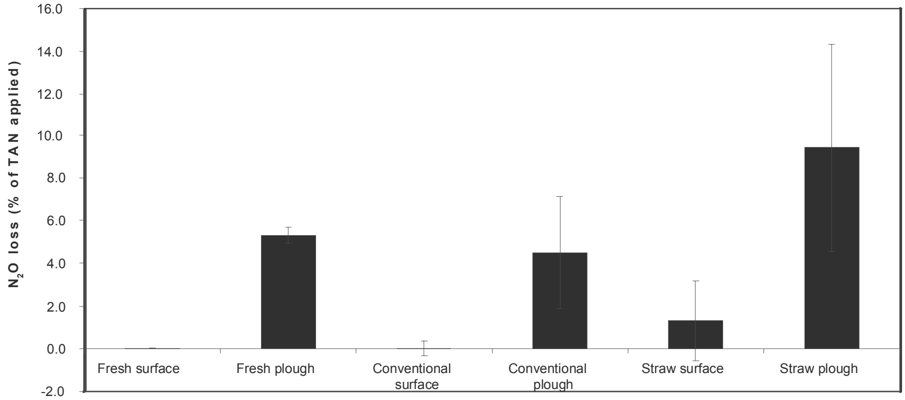

***Figure 2**. The influence of storage and incorporation on total N_2O emissions (% of ammonium-N applied) following pig FYM applications*

Stored cattle FYM also contained very small amounts of mineral N, supplying 1.5 and 1.2 kg of N ha^{-1} as ammonium and nitrate in the conventional treatment and 1.2 and 0.4 kg of N ha^{-1} respectively for the extra straw treatment Despite this, a peak in N_2O emissions (61 g N_2O-N ha^{-1} d^{-1}, conventional disced treatment) was measured 3 days after application after which emissions rates decreased to control levels (0.5 g N_2O-N ha^{-1} d^{-1}). A second peak (30 g N_2O-N ha^{-1} d^{-1}, conventional surface treatment) of N_2O emission occurred 2 weeks later after several days of rain and on the same day as a particularly high total daily rainfall quantity of *c*. 20 mm.

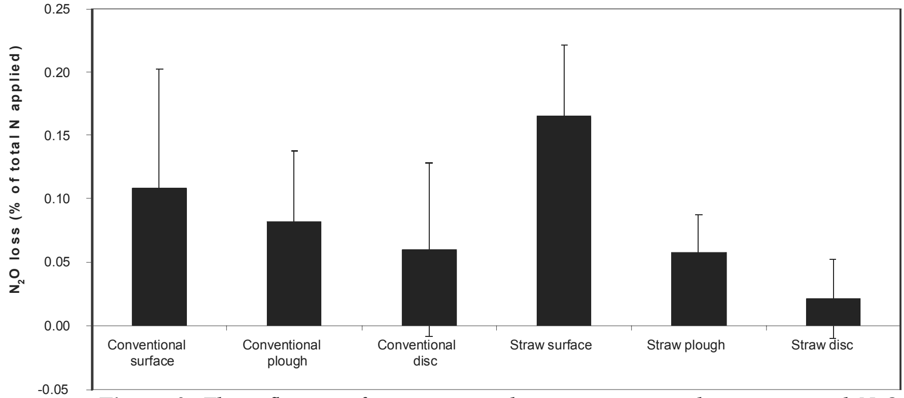

***Figure 3**. The influence of straw use and incorporation technique on total N_2O emissions (% of total N applied) following cattle FYM applications*

There were no significant ($P > 0.05$) effects of straw use or incorporation technique on cumulative N_2O emissions expressed as a % of the total N (Fig. 3) and TAN applied, although in contradiction to the results measured from the pig FYM, there is a suggestion that cattle FYM remaining on the surface of the soil resulted in greater N_2O emissions than from the incorporation treatments. Values for the % of TAN applied emitted as N_2O-N ranged from 5 to 38%. These values appear to be greater than those for the pig FYM treatments. This is probably explained by the presence of NO_3-N in the cattle FYM at the time of application.

The percentage of total N applied lost as N_2O (Figs 1 & 3) was similar to losses calculated in previous experiments at the same site and those in the literature (Watanabe et al., 1997; Chadwick et al., 2000; Thorman et al., 2003) ranging from 0.003-2.03% total N lost as N_2O. All values were smaller (generally < 0.20%) than the default IPCC emission factor for manure spreading uncorrected for the fraction of N lost as NH_3 and NO_x i.e. 1.0% of total N applied. This was probably a result of the low ammonium-N content of the FYM, which was presumably lost as gaseous and aqueous forms during the extended storage period. Also, emissions were only measured for 2-3 months, whereas the IPCC factor relates to the estimate over one calendar year, Notably, emissions from the pig FYM increased over the last month of the measurement period, particularly from the fresh and conventional plough treatments. This was likely to be in response to a rise in temperature, coupled with several heavy rainfall events. Clearly at the end of the measurement period the manure was still stimulating emissions, resulting in an underestimation of the total emission.

CONCLUSIONS

The results indicate that there was no consistent effect of incorporation on N_2O emissions, however, storage may be an efficient management strategy to reduce N_2O losses at spreading because of the reduction in manure available N content.

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