Methodological approach to identifying the properties of a novel organomineral fertiliser – *Part I: agronomic aspects*

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SUMMARY

This paper summarises the methodology used in this research for evaluating the agronomic properties of organomineral fertilisers (OMFs). This involves a series of interconnected experiments conducted under controlled conditions and field-scale trials. The process for the production of OMFs was recently developed by a major UK water company and appears to be a sustainable solution for the recycling of sewage-sludge to agriculture. Preliminary results arising from the experiments indicate that the formulated OMFs are suitable for application on agricultural land. Experimental data was statistically analysed using analysis of variance and least significant differences to compare means.

Key words: organomineral fertiliser (OMF), sewage-sludge, nitrogen

INTRODUCTION

The water industry is under increasing pressure resulting from rigorous legislation both at UK and EC levels, regarding the production and disposal of sewage-sludge. Current levels of production are set to increase in response to population growth and stringent requirements for the treatment of effluents (Defra, 2007). Recycling to agricultural land is regarded by the UK Government as 'the best practicable environmental option' and represents the main disposal route (65%) followed by incineration (20%) and landfill (< 10%). There is also a cost advantage of recycling with respect to incinerating and landfilling. However, the increase of current levels of sewage-sludge up-take by farmers is restricted by a number of problems; e.g. spreading, transport, and handling of bulky materials. In addition, the use of sludges in agriculture has been restricted due to their variable chemical composition (Sommers *et al*., 1976) and the fact that the amount of nitrogen available following application is poorly understood (Bowden and Hann, 1997). The combination of these factors determines a highly variable agronomic performance. Recently, a novel method of blending mineral fertilisers with biosolids to produce organomineral fertilisers (OMFs) has been developed by United Utilities plc. This development would significantly contribute to address the problems highlighted above.

The aim of this work is to determine the effects of the use of OMFs in agriculture and to identify the most advantageous OMFs' formulations for a number of crops and soil types. This paper explains the methodological approach used to fulfil the aim of this research through a series of interconnected studies conducted under controlled conditions and field-scale trials. The work described herein corresponds to year one of the Engineering Doctorate Programme at Cranfield University.

METHODOLOGY

This section explains how the OMF products have been specified; e.g. chemical composition, and sets out the methodology employed to determine the agronomic value and the nutrient release characteristics of the formulated OMFs. Specifications of the physical characteristics of the formulated OMFs are given in Antille *et al*. (2008).

OMF formulation

Using the method developed by United Utilities plc, two OMFs with different N-concentrations were formulated; OMF_{10} (10% N) and OMF_{15} (15% N). For this, the following aspects were taken into account: ***a.*** guidance given by United Utilities plc; ***b.*** nutrient composition of 'raw material'; i.e. digested cake; ***c.*** typical N, P, and K application rates in wheat; and ***d.*** soil-P indexes in the surroundings of Warrington.

Higher N concentrations than 10% and 15% are technically possible but this would not only result in increased manufacturing costs, but also and most importantly, in a reduction in the volume of sewage-sludge being disposed. The digested cake is generally quite unbalanced in its nutrient composition; a typical N:P:K composition would be 3:4(+):0.15-0.25. This gives a low N:P ratio which determines that sewage-sludge applications based exclusively on crop-N requirements (**Table 1**) could lead to rapid build up of soil-P. Therefore, current N:P ratios would need to be increased to a point where crop demand for P could be met with existing P in the cake and then make up the difference in N by adding N to the cake (**Table 2**). This is possible by blending the cake with urea (46% N). The same can be done with K but in this case the difference between the concentration of K in the cake and the requirement of the crop can be made up with KCl (52% K). This would ensure that soil-P index was not increased while crop requirements of N and K could be met.

It is important to highlight that an important proportion of soils in the NW region were reported to have P-index 3 (Skinner *et al.*, 1992) and that there is usually no intention of building up the existing P-level.

Table 1: Required application rates of P and K according to their levels in the soil.

	Application rate (kg ha^{-1})	
Level in the soil	P_2O_5	K_2O
Low	88	95
High	55	53

Table 2: Nutrient application rates and correspondent ratios assuming the rate of N is 200 kg ha^{-1}

Application rate (kg ha^{-1})			
N	P_2O_5	K_2O	Ratio
200	88	95	≈ 2.2-1-1
200	88	53	≈ 2.2-1.5-1
200	55	95	≈ 4-1-2
200	55	53	≈ 4-1-1

Using the ratios shown in **Table 2**, the formulation of the OMFs can be inferred; taking for example the cases where P and K application rates are either high or low, the resultant OMFs' formulations given in % as N:P:K would be: 15:4:4 (OMF_{15}) and 10:4:4 (OMF_{10}) with P and K expressed in % as P_2O_5 and K_2O respectively. The two intermediate situations in **Table 2** were discarded as it was considered more cautious to obtain products that could be used either in soils having low or high P and K indexes and utilise a different fertiliser source to meet the crop requirements in these intermediate situations.

OMF agronomic value

In order to quantify the agronomic value and the nutrient release characteristics, three sets of experiments were established. These include the use of pots (greenhouse), plots (field), and incubators (laboratory).

Experiment 1: Pot trial

This experiment aims at quantifying the effects on rye-grass (*Lolium perenne L.)* from the application of OMFs. This is crucial to determining the OMFs' agronomic value and deciding the most appropriate application rates strategies. In addition, it will provide a valuable feedback on the proposed formulations.

This trial comprises two soil types, a sandy loam (Cottenham series; King, 1969) and a clay loam (Holdenby series; King, 1969). The latter soil is commonly found in the area of Warrington where United Utilities plc is based. A total of 8 kg of air-dried soil was used for each pot and a layer of 2.5 cm of gravel was placed at the bottom of the pot to allow free drainage (**Figure 1**).

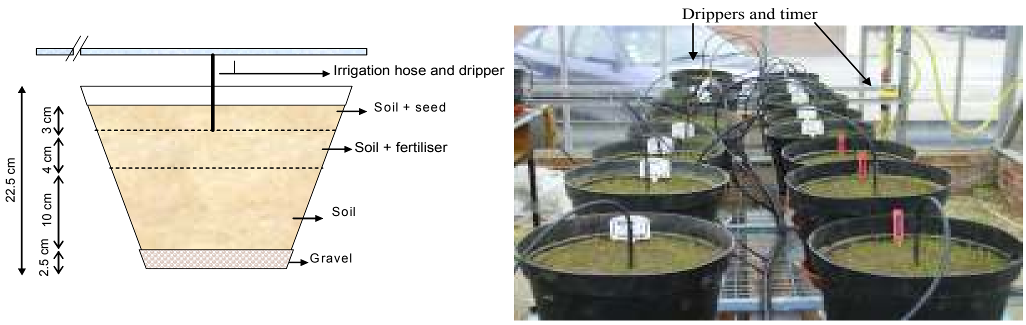

Figure 1: Diagram of a pot (left) and pots with established grass and irrigation system (right).

A dripper irrigation system was installed to maintain the soil at around field capacity all the time but avoiding excess of water leading to leaching and anaerobic conditions. The grass was sown at a density of 4 g of seeds per m^2 which is a standard rate for rye-grass. Sowing took place on April 27th 2007. The experiment comprises the use of four different fertilisers materials; i.e. OMF_{15}, OMF_{10}, cake (3% N) and urea (46% N), and two application rates; i.e. R_1 (150 kg N ha^{-1}) and R_2 (300 kg N ha^{-1}) and a control with no fertiliser added. A total of three cuts were possible during the growing season without any further fertiliser application.

Experiment 2: Plot trial

The aim of this trial is to identify the response of winter wheat (*Triticum aestivum L.*) to increasing application rates of nitrogen. This would allow determining the optimum OMFs' application rates. The trial is being conducted at Silsoe Farm on a sandy loam soil (Cottenham series; King, 1969) and it will run for 3 consecutives growing seasons in the same experimental site; thus, the residual effect of applied OMF-N can be quantified and taken into account when deciding N-application rates in the long term. A total of 60 plots (**Figure 2**) were marked out in the field with N-application rates ranging from 0 (control) to 250 kg N ha^{-1} in intervals of 50 kg N ha^{-1} and using the same fertiliser materials as those described above for the pot experiment.

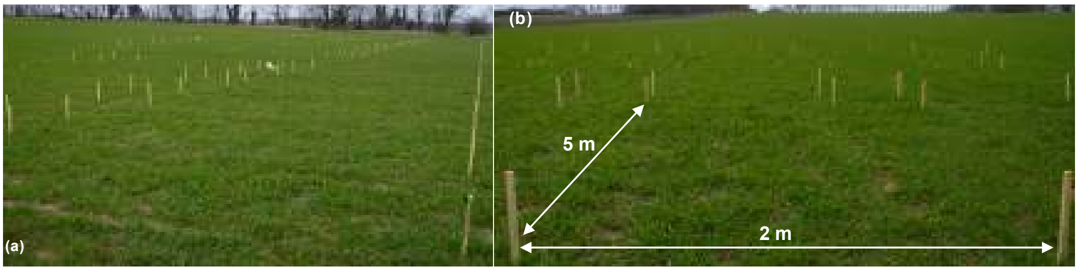

Figure 2: Overview of plot experiment in Avenue Field – CU@S **(a)**; and **(b)** close-up plot.

The plots were designed to have 2 m by 5 m to facilitate the operation of a Deutz Fahr M660 plot combine-harvester.

A decision was made to carry out the first N-application on March 27th 2007 using UAN (urea ammonium nitrate; 32% N) at a rate of 90 kg N ha^{-1} in order to avoid losses of yield since the production of the OMFs could not be completed by the time the fertiliser was required. A second N-application was then carried out on May 17th 2007 once the OMFs became available. This took place immediately before the flag leaf was displayed.

Experiment 3: Incubation trial

The chemical compositions of the OMFs were designed for the application on crops in the early spring. The mineral fraction of the OMFs would ideally produce a quick burst of N to cover the requirements of the crop for the main growth period; thereafter, it would continue to release N at a slower rate so that no further fertiliser dressing would be required for the crop cycle. This slow-release N would come from the organic fraction of the OMF-N which would be gradually mineralised throughout the growing season. However, as this process is highly dependent on a number of factors; e.g. temperature and soil moisture content, later applications of mineral-N may be done if necessary.

The purpose of this experiment is therefore to obtain information about OMF-N release and to try and determine whether mineralised-N matches the requirement of the crop at any given time. It is therefore vitally important to be able to identify the rate of N-release over time and to quantify the proportion of N available and non-available for crop up-take. This information will help to develop appropriate application rates strategies and timing of application. The experiment is conducted under controlled laboratory conditions; i.e. temperature and soil moisture content, and uses the same soil types as those described before for ***experiment 1***.

Soil samples are taken monthly for analysis of available N and extractable P and will run for a period of 6 months.

CONCLUSIONS

The development of OMF products will bring about a sustainable solution for the recycling of biosolids to agricultural land. This would contribute to reduce the cost of disposal by diverting more sewage-sludge through the agricultural route and would provide the users with more reliable products; thereby, increasing current levels of up-take. Preliminary experimental results both in the greenhouse and field have shown the suitability of formulated OMFs for application in winter wheat and grassland.

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