Agronomic value of alkaline stabilised sewage sludge solids

Valeur agronomique de boues de station d'épuration solides, stabilisées par alkalinisation.

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Abstract

« Agri-Soil » is an organic fertiliser made by mixing dewatered sludge (32-35 % DM) with cement kiln dust and composting aerobically in windrows. Two field experiments compared the P or K value of Agri-Soil for five consecutive annual spring barley crops with inorganic fertiliser P or K. All Agri-Soil and inorganic fertiliser treatments gave higher yields than controls, but there was no yield response to increasing application rate of Agri-Soil or fertiliser P or K. Yields of sludge amended or fertilised plots were therefore averaged over the five crops and compared. Agri-Soil gave higher mean grain yields than fertiliser P or K, higher thousand grain weights and more grains per ear than KCl (not determined for fertiliser P) and higher straw yield than fertiliser P. These effects may have been due to, inter alia, higher soil pH and alleviation of sulphur deficiency.
Keywords : Alkaline sewage solids, barley yield, nitrogen, phosphorus, potassium, sulphur

Résumé

« Agri-sol » est un fertilisant organique préparé par mélange de boues de station d'épuration déshydratées (32-35% de MS) et de poussière de « ciment » compostée en andains. Deux essais au champ ont permis de comparer la valeur phosphatée et potassique de Agri-sol au cours de cinq essais agronomiques sur orge de printemps avec fertilisants chimiques P ou K. Tous les traitements avec Agri-sol et engrais chimiques présentent de meilleurs rendements que les témoins, mais on n'a pas obtenu de courbe de réponse à des doses croissantes de Agri-sol ou de fertilisant P ou K. Les rendements des cultures amendées avec Agri-sol ou fertilisées ont donc été moyennés sur les cinq cultures et comparés. Agri-sol entraîne de meilleurs rendements en grain comparativement aux engrais P et K, un poids de mille grains plus élevé et plus de grains par épi et un meilleur rendement en paille que le fertilisant P. Ces effets sont peut-être dus, entre autre, à un pH plus élevé et à une moindre carence en soufre.
Mots-clés : boues solides basiques, rendement orge, azote, phosphore, potassium, soufre.

1. Introduction

The Water Service of the Department of Northern Ireland has developed the Agri-Soil process for the alkaline stabilisation and composting of sewage sludge solids prior to land spreading as a means of sludge disposal. The initial pH of the mixture of sludge and kiln dust rises above 11.0 to kill pathogens and suppress odours and declines to about 7.8 after composting. Heat generated during the composting stage further contributes to pathogen kill and increases the dry matter content of the product. Agri-Soil contains less N and P than raw sludge cake but has a relatively high K content derived from the kiln dust. It has a neutralising value ($CaCO_3$ equivalent) of 30 % (DM basis).

This paper outlines the process and describes two field experiments on contrasting soils in which the agronomic value of the product for spring barley has been investigated for five consecutive years. Some of the results from the K experiment have been reported briefly (Christie & Easson, 1997).

2. Material and Methods

2.1. The Agri-Soil Process

The Agri-Soil process was developed by Love (1990) and is shown schematically in Fig. 1. Screened and picket fence - thickened rural sludge is mixed with a cationic polyacrylamide polyelectrolyte solution to act as a flocculant and passed through a modified belt press. The solids (30-35% DM) are then mixed in a ratio of 65:35 w/w with cement kiln dust. The mixture is composted by turning daily in windrows under cover for five days to produce a short-term unstabilised material with 50-55 % DM. This can then be turned regularly in the open for a further 45 days to achieve organic stability and a DM content of 75-80 %. This process differs from the 'N-Viro Soil' process (Burnham *et al*., 1992) in its use of composting rather than accelerated drying.

2.2. The Field Experiments

The P experiment was established on a basaltic clay at Muckamore near Antrim (Irish Grid Reference J170839). Sludge cake was applied to plots (each 2.5 x 15 m) at rates of 17, 34, 51 and 68 t DM ha^{-1}. Triple superphosphate was applied to other plots at rates of 17, 35, 52 and 70 kg P ha^{-1} calculated to give approximately the same range of available P application rates assuming 50% availability of sludge total P. The actual application rates of total sludge P averaged 39, 78, 117 and 156 kg ha^{-1}. Controls received no P applications, but supplementary N and K were applied where necessary to prevent yield responses to N or K. Lime (3 t ha^{-1}) was applied before the first crop in 1992 to raise soil pH to the target value for an organic soil (16 % OM) of 6.4 (MAFF, 1994).

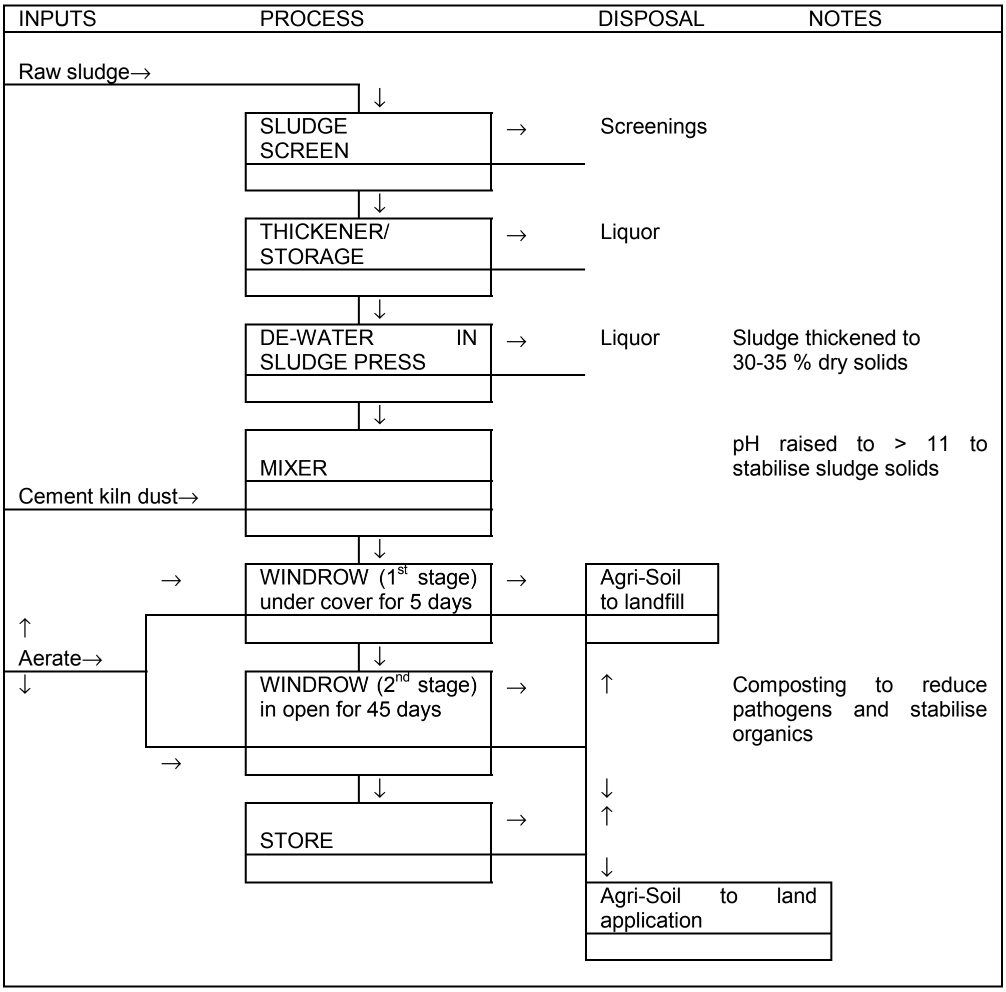

Figure 1
Agri-Soil process flow diagram

The K experiment had a similar design and was established in 1992 at Corcreeny near Hillsborough, County Down (Grid Reference J208588) on a sandy loam derived from Silurian shale and Triassic sandstone. Agri-Soil was applied to plots (each 4 x 20 m) at rates of 4, 8, 12 and 16 t DM ha^{-1}. KCl was applied to other plots at application rates of 42, 83, 124 and 166 kg K ha^{-1} calculated to give approximately the same range of K application rates. Fertiliser K application rates were based on analysis of batches of Agri-Soil made in early 1992, but subsequent batches were higher in K and the actual application rates of K in the sludge product averaged 73, 146, 219 and 292 kg ha^{-1}. Controls received no K applications, but supplementary N and P were applied where necessary to bring the total application of N and P up to recommended rates for the UK (MAFF, 1994) so that any yield responses could not be attributed to N or P. Lime (2 t ha^{-1}) was applied to raise soil pH to the target value for the mineral soil (4 % OM) of 6.7 (MAFF, 1994).

Spring barley (*Hordeum vulgare* cv. Forrester in 1992 and 1993 and cv. Chariot from 1994 to 1996) was grown at both sites. There were four replicates of nine treatments in a randomised block, giving a total of 36 plots at each site. Shoot samples were collected at the tillering stage for nutrient analysis. At harvest the grain and straw from the centre of each plot were harvested and weighed and samples collected for chemical analysis. Subsamples of grain from the K experiment were used to determine the proportion of dirt present (average < 2 %), the hectolitre weight and thousand grain weight TGWT) and plant, tiller and head densities were counted.

Soil properties were determined on composite samples collected to 15 cm depth every February using standard methods (MAFF, 1986). Plant N was determined by Dumas combustion. Other plant nutrients were determined by inductively coupled plasma atomic emission spectrometry (ICP-AES) following digestion in HNO_3. The mean yield and grain quality results for five consecutive annual crops were tested by analysis of variance.

Site	Date	DM %	Total N	Total P	Total K
				g kg^{-1} DM	
Antrim: Basaltic till clay with low available P status					
Mean	1992-1996	58.7	7.21	2.29	17.7
Hillsborough: Silurian shale sandy loam with low available K status					
Mean	1992-1996	58.3	7.88	2.46	18.3

Table 1
Dry matter (DM, %) and N, P and K (mg kg^{-1} DM) composition of the batches of Agri-Soil used from 1992 to 1996

3. Results

The DM, N, P and K concentrations of the batches of Agri-Soil applied from 1992 to 1996 are shown in Table 1. The product varied widely in DM content because the batches were not all composted for 50 days. Those applied in 1995 and 1996 were fully composted and stabilised. Mean grain and straw yields at both sites and crop quality measurements at Hillsborough are presented in Table 2. Agri-Soil produced higher grain yields than fertiliser P or K and gave higher straw yield than fertiliser P on the basaltic clay. The sludge product also gave higher grain weight and numbers per ear than fertiliser K at Hillsborough. The density of barley plants, tillers and heads was the same using fertiliser K and Agri-Soil.
Table 3 shows the soil pH (1:2.5 soil:water), bicarbonate-extractable P and exchangeable K in February 1992 (before the start of the experiment) and in February 1997 (after five annual crops). The most marked effects of the Agri-Soil were its liming effect and the increase in soil exchangeable K status. These were

more pronounced at Antrim because of the higher application rates at this site. The increases in soil exchangeable K reflected the relatively high K content of the organic manure.

Treatment	Antrim: Basaltic clay		Hillsborough : Silurian shale and Triassic sandstone sandy loam							
	Grain yield	Straw yield	Grain yield	Straw yield	Hectolitre weight	TGWT	Grain number	Plants	Tillers	Heads
Control	3.47c[a]	1.68b	4.36c	2.11b	62.6c	36.8c	17.0c	307a	806b	578b
Fertiliser P or K	4.24b	1.93b	5.34b	2.62a	63.6b	38.0b	18.0b	316a	922a	645a
Sludge cake	4.70a	2.54a	5.62a	2.61a	64.3a	38.5a	18.4a	313a	919a	667a
Significance[b] of :										
Treatment	***	**	***	***	***	***	***	NS	***	***
P or K source	***	***	*	NS	***	***	**	NS	NS	NS
P or K level	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Trtmnt X P or K source X P or K level	NS	NS	NS	*	NS	NS	NS	NS	NS	NS

[a]Means within each column followed by the same letter are not significantly different by least significant difference at the 5% significance level.
[b]By analysis of variance: ***, P<0.001; **, P<0.01; *, P<0.05; NS, not significant.

Table 2.
Mean yields of grain (15 % moisture content, t ha^{-1}) and straw DM, t ha^{-1} at Antrim and Hillsborough and grain hectolitre weight (kg), thousand grain weight (TGWT, g), number of grains ear^{-1}, and plant population data (all no. m^{-2}) at Hillsborough for five consecutive annual spring barley crops.

Date	Antrim: basaltic clay				Hillsborough: Shale sandy loam			
(Feb.)	Treatment (ha^{-1})	pH	P	K	Treatment (ha^{-1})	pH	P	K
1992	None	5.9[a]	8	160	None	6.2[b]	42	116
1997	0 (Control)	6.9	5	175	0 (Control)	6.4	29	75
	17 kg P	6.8	9	152	42 kg K	6.5	29	108
	35 kg P	6.8	9	146	83 kg K	6.9	35	173
	52 kg P	7.0	12	166	124 kg K	6.6	34	160
	70 kg P	7.1	20	170	166 kg K	6.4	29	175
	39 kg Sludge P	7.9	13	419	73 kg Sludge K	7.1	33	123
	78 kg Sludge P	8.0	20	653	146 kg Sludge K	7.4	35	159
	117 kg Sludge P	8.0	28	799	219 kg Sludge K	7.6	35	196
	156 kg Sludge P	8.1	32	1103	292 kg Sludge K	7.4	34	204

[a]3 t and [b]2 t lime ha^{-1} were applied before the first crop in 1992

Table 3.
Soil pH (in water), Olsen P (mg l^{-1}) and exchangeable K (mg l^{-1}) before the experiments (1992) and after five consecutive annual barley crops (1997).

The nutrient status of the barley shoots at the tillering stage allows comparison between the nutrient supplying capacity of the different treatments (Table 4). The most consistent effect over both sites was the higher concentration of S in the shoots receiving Agri-Soil, with the sole exception of the 1994 crop at Hillsborough.

4. Discussion

Agri-Soil produced higher barley grain yield on average at both sites (and higher grain quality at Hillsborough) than inorganic sources of fertiliser P or K over a five-year period of continuous cropping. Straw yield was also higher at Antrim and unaffected at Hillsborough. This was unlikely to be due simply to the higher range of P or K application rates in the sludge product because there was no yield response to increasing Agri-Soil or inorganic fertiliser application rate at either site.

Another possible explanation is that the sludge solids may have improved soil condition by supplying additional carbon. However, this is unlikely to be an important factor because the Hillsborough soil has a relatively high organic C content for a temperate mineral soil (2.4 % in the top 15 cm) and the Antrim clay would be classified by MAFF (1994) as an organic soil. A more likely explanation is that the high soil pH maintained by the sludge product may have contributed to the yield effect, together with alleviation of S deficiency. These two factors may have interacted with plant growth. Murphy (1990) described the low atmospheric inputs of S to soils in Ireland and reported responsiveness to S in Irish sandy soils with less than 3 % organic C. Sulphur in Agri-Soil is derived not only from the sewage sludge, but also from the cement kiln dust which typically contains 5 % S (Love, 1990).

It is unlikely that S is the only nutrient involved in the yield response to Agri-Soil. Mean offtakes of N, P, K and S in grain and straw were all higher in the Agri-Soil treatments than the fertilised plots (data not shown). Alhough the product does not have a high N concentration, its liming effect may have stimulated mineralisation of soil organic N, especially in the organic basaltic clay, an effect observed in forest soils to which Agri-Soil was applied (Luo & Christie, 1995). Thus, lime stabilised and composted sludge solids from rural sludges with relatively low concentrations of heavy metals may be a useful seedbed fertiliser for cereals when incorporated into nutrient management plans.

5. References

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