Digestate: Crop available nitrogen supply to winter cereals

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Abstract

Digestate (biofertiliser) outputs from anaerobic digestion processes typically have a high readily available nitrogen (RAN) content and can be used as a replacement for manufactured fertiliser nitrogen (N) applications. However, few studies in the UK have quantified the crop available N supply from different digestate types, application timings and methods. Field-scale experiments were undertaken to investigate the effects of contrasting digestate types (food and manure-based) and cattle slurry application timings (autumn and spring) on winter wheat grain yields and quality at two sites (Loddington; Leicestershire and Brawdy; Pembrokeshire) in harvest year 2011.

The N use efficiency of the spring applied digestate and cattle slurry applications was greater (*c*.40% of total N applied for food-based digestate and *c*.20% for manure-based digestate/cattle slurry) than from the autumn timings (*c*.5% of total N applied for all three organic materials), most probably as a result of over-winter nitrate leaching losses. Notably, the N use efficiency of spring applications reflected the RAN content of the liquid organic materials: food-based digestate > manure-based digestate = cattle slurry.

Introduction

Anaerobic digestion involves the breakdown of organic materials in the absence of oxygen to produce methane (a biogas) which can be burnt to generate electricity. The process also produces (liquid) digestate as a by-product, which can be recycled to agricultural land as a source of nutrients. Currently, around 1 million tonnes of digestate are applied to agricultural land in the UK [1] and this amount is predicted to rise up to 5 million tonnes [2]. Typically, food-based digestate contains 5 kg total nitrogen (N)/cubic metre fresh weight, with *c*.80% of this in a readily available N (RAN) form i.e. potentially available for immediate crop uptake [3] [4]. However, not all of this RAN will get used by the crop, because of N losses (e.g. via ammonia volatilisation, nitrate leaching, nitrous oxide emissions) to the wider environment.

Nitrogen is the single most important nutrient influencing crop yields on (most) mineral soils, with applications at the optimum economic rate typically doubling crop yields [5]. As food-based digestate is a new product to farmers it is important to understand its N release properties, as 'mismanagement' can result in yield penalties for farmers (through either underestimating or overestimating N supply) or undesirable environmental pollution through underestimated N supply. This is even more important for digestate than livestock slurries as food-based digestate typically has *c*.80% of its total N content in a RAN (i.e. ammonium) form, compared with pig slurry which has *c*.70% RAN and cattle slurry which has *c*.45% RAN [3] [4]. Also, making full allowance for the N supplied by organic materials is a requirement of the Nitrate Vulnerable Zones Action Programme in England and Wales [6] [7].

Methodology

To assess the crop available N supplied by digestate and cattle slurry applications, replicated experiments were established at Brawdy (Pembrokeshire) and Loddington (Leicestershire); both sites growing winter wheat. Two contrasting digestate types (food-based and manure-based) and cattle slurry were applied at different timings (autumn 2010 and spring 2011), using commercial precision application equipment (i.e. bandspreading equipment). Details of the liquid organic material applications are summarised in Table 1.

A range of manufactured fertiliser N (0, 50, 100, 150, 200 and 250 kg N/ha) rates were also applied. To assess the N fertiliser replacement value of the liquid organic materials applications standard internationally accepted methodologies [8] [9] [10] were used. Crop grain yield responses to manufactured fertiliser N were compared with the liquid organic materials to calculate the N fertiliser replacement value and N use efficiency of the digestate and slurry applications [11].

Table 1. Liquid organic material application details and analyses

Site		Organic material	Application rate (m^3/ha)	Dry matter (%)	pH	Total N (kg/m^3)	Ammonium-N (kg/m^3)	Ammonium-N as % of total N
Brawdy (Pembrokeshire)								
	September 2010	Food-based digestate	40	4.7	7.8	5.39	3.52	65
		Manure-based digestate	38	7.5	7.9	3.72	1.24	33
		Cattle slurry	60	7.5	6.5	2.49	1.16	47
	March 2011	Food-based digestate	26	4.5	8.5	4.86	3.23	66
		Manure-based digestate	36	6.9	8.0	4.06	1.47	36
		Cattle slurry	38	7.8	7.3	2.63	1.23	47
Loddington (Leicestershire)								
	September 2010	Food-based digestate	48	6.0	8.5	6.20	4.18	67
		Manure-based digestate	38	6.7	8.3	3.98	2.19	55
		Cattle slurry	58	4.0	7.4	2.01	0.92	46
	March 2011	Food-based digestate	35	1.3	8.7	4.32	3.70	86
		Manure-based digestate	45	7.5	7.9	4.19	1.91	46
		Cattle slurry	58	7.2	7.3	3.46	1.23	36

Results

Winter wheat yields and N offtakes

At Brawdy, the application of digestate (food and manure-based) and cattle slurry in spring 2011 increased winter wheat grain yields by 1.6-2.6 t/ha, and N offtakes by between 16-28 kg N/ha compared with the untreated control ($P<0.01$). There were no differences in yield or grain N offtakes ($P>0.05$) between the autumn applied digestate/slurry treatments and the untreated control.

At Loddington, the application of food-based (in both autumn and spring 2011) and manure-based digestate in spring 2011 increased winter wheat grain yields ($P<0.01$) by 1.0-1.7 t/ha, and N offtakes ($P<0.05$) by around 20 kg N/ha compared with the untreated control. Similarly, grain N offtakes from the food and manure-based digestate applications in spring 2011 were 15-20 kg N/ha higher than the autumn manure-based digestate and cattle slurry treatments ($P<0.05$).

Nitrogen use efficiency

At Brawdy, N use efficiency (compared with manufactured fertiliser N) of the spring applied digestates and cattle slurry was higher ($P<0.01$) than the autumn treatments, most probably reflecting over-winter nitrate leaching losses (Figure 1). Spring applied food and manure-based digestate had N use efficiencies of 39% and 15%, respectively, compared with autumn food and manure-based digestate efficiencies of 2% and 1%, respectively.

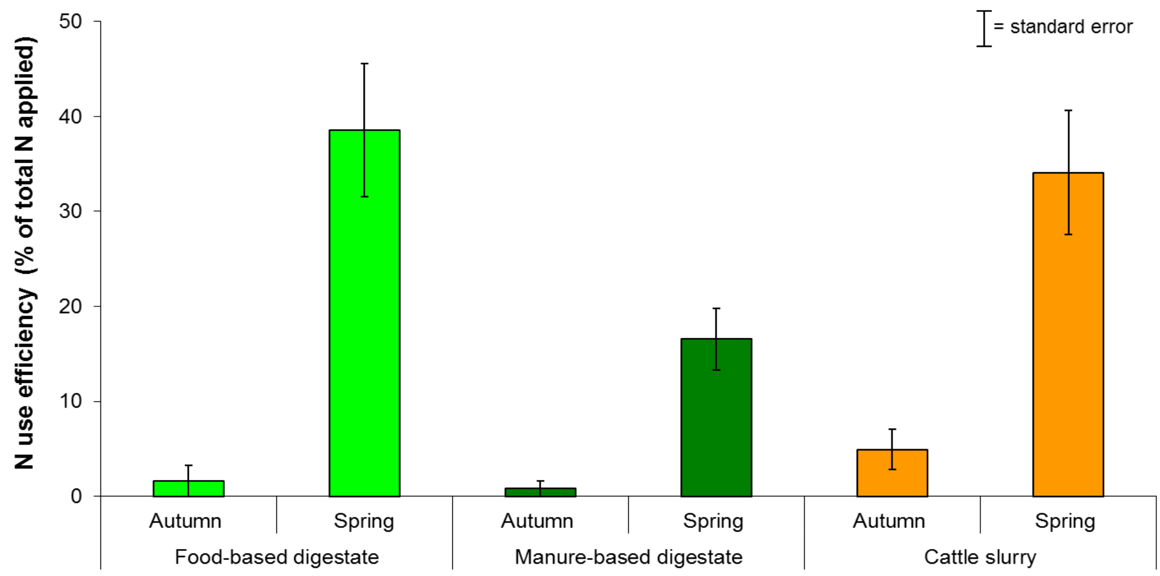

Figure 1. Liquid organic material nitrogen use efficiencies at Brawdy (2010/11)

At Loddington, N use efficiency (compared with manufactured fertiliser N) of the spring applied food-based digestate and cattle slurry was higher (P<0.01) than the autumn applied treatments, again most probably reflecting over-winter nitrate leaching losses (Figure 2). Spring applied food and manure-based digestate had N use efficiencies of 36% and 23%, respectively, compared with autumn food and manure-based digestate efficiencies of 9% and 10%, respectively.

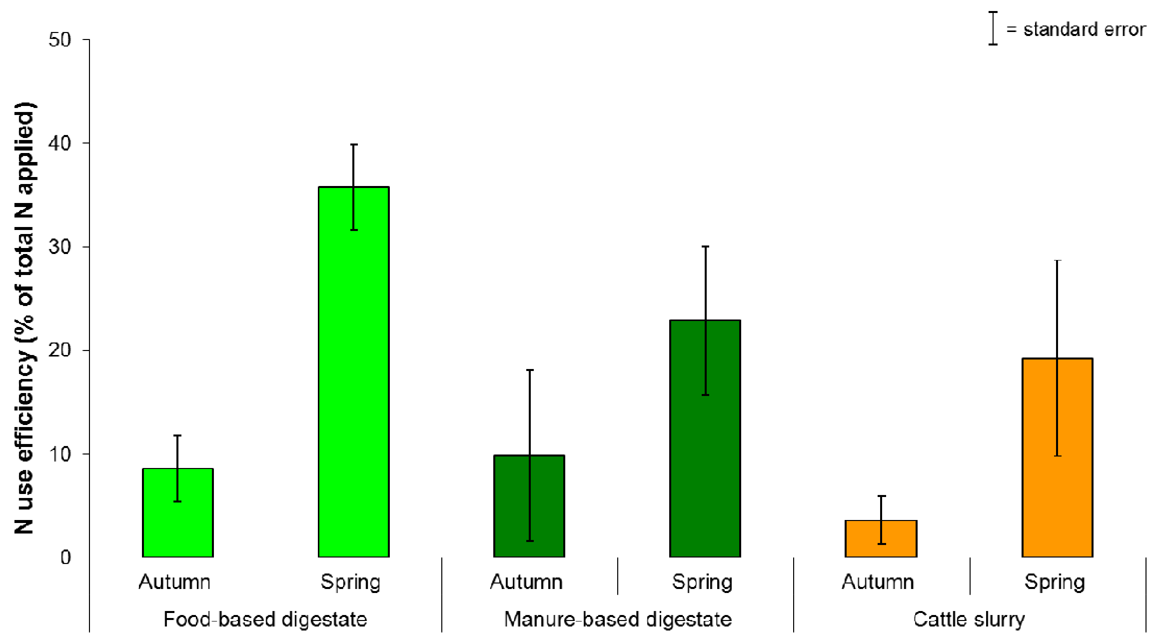

Figure 2. Liquid organic material nitrogen use efficiencies at Loddington (2010/11)

Conclusions

The N use efficiency, compared with manufactured fertiliser, of the spring applied digestate and cattle slurry applications was greater (*c*.40% of total N applied for food-based digestate and *c*.20% for manure-based digestate/cattle slurry) than from the autumn timings (*c*.5% of total N applied for all three organic materials), most probably as a result of over-winter nitrate leaching losses. Notably, the N use efficiency of the spring applications reflected the RAN content of the liquid organic materials: food-based digestate > manure-based digestate = cattle slurry; with ammonia emissions most likely responsible for the 'gap' between the amount of RAN applied and crop N recovery.

Acknowledgements

Funding of this work by the Waste and Resources Action Programme and the Department of Environment, Food and Rural Affairs is gratefully acknowledged.

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