

Amenity grassland quality following anaerobic digestate application

Article

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1 Short running title: Digestate application to grasslands

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3 Amenity grassland quality following anaerobic digestate application

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5 Mark Pawlett¹, Andy Owen² and Mark Tibbett³

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8 1 School of Energy, Environment and AgriFood, Cranfield University, UK

9 2 ICL, Koeweistraat 4, 4181 CD, Waardenburg, The Netherlands

10 3 Centre for Agri-environmental Research and the Soil Research Centre, School of

11 Agriculture, Policy and Development, University of Reading, UK

12

13

14

15

16

17

18 Correspondence

19 Centre for Agri-environmental Research and the Soil Research Centre, School of

20 Agriculture, Policy and Development, University of Reading, UK

21 Email: m.tibbett@reading.ac.uk

22 Tel: +44 118 378 6633

1 **Abstract**

2

3 Anaerobic digestate applied to land is a source of readily available nutrients, yet there is
4 a paucity of knowledge regarding effects on grassland. To address this, we
5 investigated the viability of using digestate as an alternative to mineral fertilizer for
6 *Lolium perenne* L. (ryegrass) grassland maintenance. We present findings of two
7 independent field-trials, where food-waste digestate was applied over two growing
8 seasons at two rates (100 and 200 kg N ha⁻¹ y⁻¹) and compared to mineral fertilizer
9 (N:P:K-12:4:6 @ 100 kg N ha⁻¹ y⁻¹) and control (no additions) plots. *L. perenne*
10 nutrition (N, P and K), chlorophyll and sward composition were assessed in the summer
11 and autumn to observe treatment and seasonal effects. The sward benefited from
12 digestate application in the summer with reduced occurrence of dead *L. perenne*. Both
13 the digestate and mineral fertilizer shifted the sward composition similarly and in favor
14 of *Poa annua* L. in summer and *L. perenne* in autumn, with reduced broad-leaved weeds
15 and bare soil coverage regardless of season. Quantities of foliar N and K uptake were
16 similar between the digestate and mineral fertilizer, however the highest rate of
17 digestate application was required to supply similar quantities of P to the grass
18 compared to the mineral fertilizer. Grass chlorophyll was not adversely affected by the
19 high ammonium-N in the digestate. These broadly positive results for digestate

- 1 present opportunities for the development of digestate use as a fertilizer on amenity
- 2 grassland such as outfields in sports facilities, parks, and road verges as well as showing
- 3 potential for supplementing the fertility of pasture systems.
- 4
- 5 **Keywords**
- 6 Anaerobic digestate; *Lolium perenne*; plant nutrients; sward composition.

1 **Introduction**

2

3 The global interest in the production of biogas has led to the installation of more than
4 4,000 farm-scale anaerobic bioreactors in Europe (Weiland 2010). Biogas digestate,
5 the residual slurry by-product of the anaerobic digestion (AD) process, is a rich source
6 of plant available nutrients often recycled to soil as a fertilizer. With economic and
7 regulatory drivers, ecological advantages of using digestate as a replacement to
8 conventional mineral fertilizers are also becoming apparent (Vaneekhaute *et al.* 2013).
9 Information regarding the nutrient content of digestates is well documented (Möller and
10 Müller 2012; Nkoa 2014), however research on the use of digestates as a fertilizer
11 remains in its infancy (Teglia *et al.* 2011; Nkoa 2014). Specifically, more long-term
12 field-scale research of digestate application is required on grasslands
13 (Andruschkewitsch *et al.* 2013). It is recognized that digestate application increases
14 crop (Garg *et al.* 2005; Möller *et al.* 2008; Terhoeven-Urselmans *et al.* 2009) and
15 *Lolium perenne* (ryegrass) production (de Boer 2008; Gunnarsson *et al.* 2010), but also
16 has inhibitory effects on *Vigna radiate* L. Wikzek (Mung bean) germination (Kataki *et*
17 *al.* 2017). Also, mineral fertilizers are known to affect species composition in pasture
18 (Santamaria *et al.* 2014) and grasslands (Lanta *et al.* 2009). With the exception of
19 Dahlin *et al.* (2015), who reported increased *L. perenne* and reduced *Trifolium pratense*

1 L. (red clover) after digestate amendment in a pot-based study, there remains a paucity
2 of information on the effects of digestate on nutrient uptake and sward composition in
3 field-based grassland studies.

4 We aimed to identify the effectiveness of using digestate from food waste as a
5 fertilizer for *L. perenne* by comparing its effects on nutrient (NPK) uptake and sward
6 composition to mineral fertilizer application. Two field-trials were designed that
7 differed in respect to soil texture and rainfall. We hypothesized that digestate would
8 alter sward community composition and improve foliar nutrition content compared to
9 mineral fertilizer inputs. We were also interested to investigate how these responses
10 might vary with season.

11

12 **Materials and methods**

13

14 **Experimental design**

15 The field experiments, previously described in Pawlett and Tibbett (2015), comprised of
16 12 plots (5m x 5m with a 0.5m boundary between plots) arranged in a randomised block
17 design (four treatments and three replicates) at two locations: (i) Silsoe (E England; 52°
18 00' N and 0°26' W; 67 m.a.s.l.), and (ii) Myerscough College (NW England; 53° 44' N
19 and 2° 88' W; 12 m.a.s.l.). Locations differ in annual rainfall (584mm at Silsoe

1 compared to 998mm at Myerscough), soil texture (sandy loam at Silsoe, and a silty clay
2 loam at Myerscough) and available P and K concentrations, which were 69 and 13 mg P
3 kg⁻¹ and 236 and 131 mg K kg⁻¹ for Silsoe and Myerscough respectively. The
4 dominant species was *L. perenne* L (perennial ryegrass) which was maintained at 20mm
5 (clippings collected) using a cylindrical mower. *L. perenne* was selected as it is
6 commonly sown on amenity and agricultural grasslands. The experimental design
7 comprised of fresh PAS110 (Publically Available Specification: the UK industry quality
8 specification) digestate (Table 1) of food origin (multiple sources) in slurry form applied
9 based on the quantity of total N (as total Kjeldahl Nitrogen to BS EN 13654-2:2001) at
10 two rates (100 and 200 kg N ha⁻¹, equivalent to 22 and 44 t/ha respectively at 0.45% N),
11 a mineral fertilizer applied at 100 kg N ha⁻¹; and a control (no additions). Application
12 rates (based on N) equated to 21 and 42 kg ha⁻¹ for total K, and 7.1 and 14.2 kg ha⁻¹ for
13 total P (*aqua regia* extractable P and K to BS 7755: Section 3.13:1998). The mineral
14 fertilizer was a liquid (Greenmaster Liquid Spring and Summer: Product ID
15 342GREEL0250, PC PitchCare) which consisted of 12% total N (as ammoniacal-N),
16 4% P, and 6% K. Application at 100 kg N ha⁻¹ equated to 33 and 50 kg ha⁻¹ for P and
17 K respectively. Mineral fertilizer and digestates were both applied using a watering
18 can at the same time, which was seven times throughout the trial (September 2012

1 through to October 2013).

2

3 **Sward sampling and analysis**

4 Sampling occurred on 15/07/13 (summer assessment) and 06/11/13 (autumn
5 assessment) two weeks following a digestate application. Sward samples
6 (approximately 100g fresh weight/plot) were sampled using gardening sheers for
7 nutrient analysis. Total N, P and K were determined on dried (40°C) grass material.
8 Total nitrogen was determined by Kjeldahl extraction (Rowell 1994), and total
9 potassium and phosphorus were determined as acid (hydrochloric) extractable nutrients
10 (US EPA Method 3051). Chlorophyll was analyzed as described by (Witham *et al.*
11 1971) in summer only for the Myerscough trial, but in both seasons at Silsoe. The
12 sward composition was assessed at the same time as sampling using Laycock and
13 Canaway's (1980) 10 point system, commonly used for turfgrass studies (Wheeler *et al.*
14 2000; Dunn *et al.* 2002). The quadrat was randomly placed within each plot 10 times
15 and the percentage composition of grasses (*L. perenne* at both locations and *Poa*
16 *annua*-Annual Meadow Grass at Myerscough), broad-leaved weeds, bare soil and dead
17 plants was estimated.

18

19 **Statistics**

1 Data was analyzed using a factorial ANOVA (Tukey): two field locations
2 (Myerscough/Silsoe) x four treatment variables (control, mineral fertilizer, and digestate
3 applied at 100 and 200 kg N ha⁻¹ y⁻¹) using a Repeated Measures design (summer and
4 autumn). Statistics were performed using Statsoft, Inc. (2012) STATISTICA version
5 11 (data analysis software system), with an alpha value of 0.05.

6

7 **Results and discussion**

8

9 **Sward Composition**

10 Both the digestate and mineral fertilizer shifted the sward composition in favour
11 (p<0.05) of *P. annua* (at Myerscough in summer but not autumn) or *L. perenne* (both
12 locations: autumn and not summer) with reduced (p<0.05) broad-leaved weeds and bare
13 soil coverage (Myerscough and not Silsoe: both seasons). The top digestate
14 application rate (200 kgN ha⁻¹) further reduced (p<0.05) the proportion of broad leaved
15 weeds but did not affect the rest of the sward composition (Figure 1).

16 There was little further difference in living sward composition due to digestate
17 or mineral fertilizer amendment, even where treatment effects occurred (p<0.05).
18 However, there was a notable reduction in the proportion of dead grass under digestate
19 application at both application rates (p<0.05). This only occurred in the summer

1 season at the Myerscough site and suggests that digestate application to turfgrass during
2 the summer may be favourable compared to mineral fertilizer. The reduction of dead
3 grass may be through synergistic effects of nutrients within the digestate, which
4 collectively improved grass health (Figure 1).

5

6 **Sward nutrients and chlorophyll content**

7 Foliar nutrient concentrations (Table 2) fell within ranges that suggest no deficiencies
8 (Jones 1980). Effects of both the digestate and mineral fertilizer on foliar nutrients (N
9 and K) and sward nitrogen content (Table 2) content were consistent within each season
10 and field-trial locations as there were no interaction effects. However, effects on foliar
11 P concentrations were specific to the location and season. Chlorophyll concentration
12 was greater ($p < 0.05$) where either the digestate (200 kgN ha^{-1}) or mineral fertilizer
13 (both @ 100 kgN ha^{-1}) had been applied compared to the control plots, but increasing
14 digestate application rate (200 kgN ha^{-1}), had no further effect ($p > 0.05$). *L. perenne* is
15 often prone to chlorophyll loss or leaf-tip necrosis (scorching) where exposed to
16 ammonium (Watson and Miller 1996). There was no evidence that the high
17 ammonium-N (86% of total N) applied in this study caused any chlorophyll loss at
18 either of the dose application rates.

1 Application of either digestate or mineral fertilizer at 100 kg N ha⁻¹ increased
2 (p<0.05) the foliar N and K content compared to the control plots, but with no
3 difference of foliar N or K between the mineral fertilizer and digestate applied plots
4 where applied at the same rate. Increasing the digestate application rate to 200 kg N
5 ha⁻¹ further increased (p<0.05) foliar N and K. The increase of foliar N is consistent
6 with Andruschkewitsch *et al.* (2013) who also found increased N contents of *L. perenne*
7 with increasing digestate N application rate.

8 Foliar P concentration did not increase (compared to the control) where
9 digestate was applied at 100 kg N ha⁻¹ (Silsoe both seasons), however application of the
10 mineral fertilizer at the same N rate increased foliar P (p<0.05). Application of
11 digestate at 200 kgN ha⁻¹ was required to increase foliar P to a level that was greater
12 than the control (p<0.05) and similar (p>0.05) to that of the mineral fertilizer. The
13 increased application rate for effects to become apparent is likely due to the quantity of
14 P within the digestate being lower than N and K (Table 1). Where applied at 100 kgN
15 ha⁻¹, only 7.1 kg P ha⁻¹ is applied. At Myerscough in summer, digestate (100 or 200
16 kgN ha⁻¹) did not affect foliar P compared to the control in either summer or autumn.
17 Raising soil pH is commonly known to cause P to precipitate as calcium (or
18 magnesium) phosphate. The pH of the digestate was a mean of 8.38, thereby it is

1 feasible that the P within the digestate at Silsoe may be unavailable through
2 precipitation. However, the pH of the soil was 7.15 (SE 0.07) at Silsoe and 6.06 (SE
3 0.06) at Myerscough and so precipitation is not likely to occur. An alternative
4 hypothesis might be that P was not available to *L. perenne* as it was immobilized by the
5 microbial biomass. Microbial immobilization of P has also been reported after sewage
6 sludge application under a *L. perenne* sward (Smith *et al.* 2006).

7 Season and location effects of sward composition and foliar nutrients may be
8 due to differences of nutrient leaching (Burkitt 2014) and volatilization. The quantity
9 of N and K within the grass was significantly greater during autumn at both locations.
10 It is likely that soil available N was reduced in the summer through NH_4^+ -N
11 volatilization. Thereby, although increases of N occurred in the foliar tissue, it may be
12 necessary to keep applying to maintain grass health or alternatively apply before a
13 rainfall event to prevent volatilization (Bouwmeester 1985). Ryan *et al.* (2011) have
14 modelled other factors that might affect NH_4^+ -N volatilization (including method of
15 application).

16

17 **Conclusions**

18

1 Application of digestate at 100 kg N ha⁻¹ performed similarly to the mineral fertilizer in
2 respect of shift in sward composition, foliar N and foliar K. This indicates the
3 potential for food-sourced digestate as a fertilizer for *L. perenne* for grassland
4 management. However, 200 kg N ha⁻¹ y⁻¹ was required to increase foliar P to levels
5 similar to the mineral fertilizer (Silsoe). This study suggests that digestate has the
6 potential for use as an alternative fertilizer for turf-grass, but that the land manager
7 should consider as to whether digestate would deliver adequate available phosphorus.
8 This study suggests there may be opportunities for the development of digestate uses as
9 a fertilizer on amenity grassland, such as outfields in sports facilities, but may also be
10 beneficial for parks, and road verges, as well as pasture systems (where grass yield
11 would also be an important consideration). However, it may be important to consider
12 any variability between digestates, which could occur through different feedstocks and
13 digester designs.

14

15 **Acknowledgments**

16

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4

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- 7

1 Figure Legends

2

3 **Figures 1a-c** Sward composition (mean with SE) for the (a) Silsoe-autumn, (b)
4 Myerscough-summer and (c) Myerscough-autumn field-trials. Composition means of
5 individual components within each time and location with the same superscripts (a, b, c)
6 are not significantly different ($P > 0.05$). Black bars Control, white bars Fertilizer,
7 spotted Digestate at 100 kg N ha⁻¹, striped bars Digestate at 200 kg N ha⁻¹.

Table 1 Digestate Characteristics (n=7)

Analysis	mean	SE
Total solids (%)	3.31	0.16
pH	8.38	0.02
Conductivity 1:6 ($\mu\text{S}/\text{cm}$)	5614	263
Total N (% w/w)	0.45	0.03
Ammonium-N (mg kg^{-1})	3960	245
Total P (mg kg^{-1})	327	6
Total K (mg kg^{-1})	938	82

Table 2 Foliar nutrient and chlorophyll concentration

Nutrient	Treatment	Myerscough		Silsoe	
		Summer	Autumn	Summer	Autumn
N (% w/w)	Control	3.12 ^a	4.56 ^a	1.36 ^a	2.66 ^a
	Fertilizer	3.16 ^b	4.76 ^b	1.79 ^b	3.56 ^b
	Digestate: 100 kg N ha ⁻¹	3.16 ^b	4.85 ^b	1.71 ^b	3.47 ^b
	Digestate: 200 kg N ha ⁻¹	3.55 ^c	5.18 ^c	2.07 ^c	4.12 ^c
	Pooled SE	0.10	0.18	0.10	0.18
	Significance	***	***	***	***
P (% w/w)	Control	0.44 ^a	0.37 ^a	0.32 ^a	0.45 ^a
	Fertilizer	0.48 ^a	0.41 ^a	0.38 ^{bc}	0.57 ^b
	Digestate: 100 kg N ha ⁻¹	0.46 ^a	0.41 ^a	0.35 ^{ab}	0.48 ^a
	Digestate: 200 kg N ha ⁻¹	0.42 ^a	0.40 ^a	0.40 ^c	0.55 ^b
	Pooled SE	0.01	0.01	0.01	0.01
	Significance	***	***	***	***
K (% w/w)	Control	2.82 ^a	3.41 ^a	1.58 ^a	2.20 ^a
	Fertilizer	2.98 ^b	3.44 ^b	1.93 ^b	2.72 ^b
	Digestate: 100 kg N ha ⁻¹	2.90 ^{bc}	3.68 ^{bc}	1.85 ^{bc}	2.71 ^{bc}
	Digestate: 200 kg N ha ⁻¹	3.06 ^c	4.12 ^c	2.00 ^c	2.94 ^c
	Pooled SE	0.08	0.19	0.08	0.19
	Significance	**	**	**	**
Chlorophyll (mg g ⁻¹)	Control	1.94 ^a	-	1.18 ^a	1.17 ^a
	Fertilizer	2.28 ^b	-	1.67 ^b	1.31 ^b
	Digestate: 100 kg N ha ⁻¹	2.27 ^{ab}	-	1.65 ^b	1.62 ^b
	Digestate: 200 kg N ha ⁻¹	2.74 ^b	-	1.66 ^b	1.54 ^b
	Pooled SE	0.14		0.13	0.13
	Significance	**		*	*

** $P < 0.01$, *** $P < 0.001$. Means with the same superscripts (a, b, c) within each location and season within the column are not significantly different ($P > 0.05$). – not determined