Repeated application of anaerobic digestate, undigested cattle slurry and inorganic fertilizer N: Impacts on pasture yield and quality

Walsh, J.J.; Jones, Davey L.; Chadwick, David; Williams, Arwel

Grass and Forage Science

DOI:
10.1111/gfs.12354

Published: 01/09/2018

Peer reviewed version

Repeated application of anaerobic digestate, undigested cattle slurry and inorganic fertiliser N: impacts on pasture yield and quality

J.J. Walsh, D.L. Jones, D.R. Chadwick, A.P. Williams*

School of Environment, Natural Resources & Geography, College of Natural Sciences, Bangor University, Gwynedd, LL57 2UW, UK

* Corresponding author. Tel.: +441248 382637; fax: +44 1248 354997.

E-mail address: prysor.williams@bangor.ac.uk (A.P. Williams)

Running title: Impact of organic & inorganic fertiliser additions on pasture quality

Abstract

The growth of on-farm anaerobic digestion (AD) has generated significant quantities of digestate for use as a soil amendment. However, relative to other organic and inorganic fertilisers, only limited field trial data exists on the effect of repeated applications of digestate to temperate grasslands. Here, we compare yields and grass quality (protein and digestibility) from a field trial of a mixed pasture ley (ryegrass and clover), following the application of five different fertiliser types (liquid digestate generated from anaerobically digested slurry, dry fibre digestate, undigested slurry, ammonium nitrate and an NPK compound fertiliser) in comparison to a no-fertiliser control. Application rates were normalised in terms of nitrogen (N) and were added as a split dose, with 100 kg N ha^{-1} added prior to the first harvest and an additional 50 kg N ha^{-1} supplied after the first harvest, every year for three years. Overall, our results showed that applying both forms of digestate or undigested slurry gave grass yields that matched those obtained with one compound inorganic fertiliser, and better than those from a straight N inorganic fertiliser. No differences were found with regards to digestibility or sward N-content (hence calculated protein) between any treatments. Although the trial was conducted at only one site, the results indicate that inorganic fertilisers can potentially be replaced by digestate without compromising grassland productivity.

Keywords: Biogas, Feed value, Greenhouse gas emissions, Livestock

1. Introduction

As global demand for food continues to increase, so too will agricultural demand for nutrients. Satisfying this demand through reliance on inorganic (synthetic) fertiliser is expensive. It also increases greenhouse gas (GHG) emissions due to the energy-intensive production process (Ecoinvent, 2007) and emissions from soils, post-application. These economic and environmental concerns, coupled with increased demand for low-carbon energy, mean that there is increasing interest in anaerobic digestion (AD) as an alternative source of nutrients (Demirer & Chen, 2005). AD is the decomposition of organic resources in the absence of oxygen to produce biogas (typically 50-70% methane) and a digestate fertiliser (Masse et al., 2011). The biogas can be burnt to generate renewable energy and heat, and the digestate is an organic fertiliser which can be applied to land. The digestate can be separated into liquid and dry fibre portions, and although it varies with the separation process used, the dry fibre retains the greatest amount of P and has a similar texture to compost (dry matter (DM) content of ~20%); whilst typical DM for the liquid digestate will be 4-6%, and is associated with low P and high N contents (Moeller et al., 2010).

Inorganic fertilisers are often considered to represent a more effective and controllable source of plant nutrients than organic fertilisers; however, the latter enhance soil organic matter which improves soil structure, porosity and drainage (Choudhary et al., 1996), especially so dry fibre digestate, which has higher levels of organic matter. Further, as the release of nitrogen from organic sources is sustained over a longer period, there is often a residual effect from the mineralisation of nitrogen following repeated applications of organic fertilisers (Gutser et al., 2005). Compared to undigested animal manures, digestate has potentially greater plant-available nitrogen due to a greater proportion being in the form of ammonium (NH_4^+) (Möller & Müller, 2012). Nevertheless, surprisingly few field studies have sought to ascertain the agronomic benefits of digestate application; particularly so on temperate grasslands that sustain ruminant livestock farms (Möller et al., 2008; Walsh et al., 2012a). This is surprising given that AD systems are frequently found on such farms due to the availability of manures which make suitable feedstock for AD (Demirer & Chen, 2005). Furthermore, the impact of digestate application on forage quality (e.g. protein content and digestibility) has yet been studied.

The aim of this study was to determine the effects of the repeated application of different fertilisers, including AD digestate, on a mixed pasture ley over three growing seasons. The key indicators used to evaluate treatment performance were dry matter yield, pasture composition, forage protein and digestibility.

2. Materials and methods

2.1 Experimental design

The experimental field site was located on freely draining agricultural grassland located at Bangor University's Henfaes Research Centre, North Wales (53°14'05''N, 4°00'50''W). The sward contained a newly sown mixture of perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens*, L.) and was previously subject to sheep grazing (ca. 15 ewes ha^{-1}). The soil has a clay-loam texture and is classified as a Eutric Cambisol (of the 'Denbigh' series) and is derived from mixed glacial till. The trial was conducted over a three year period (2011-13).

Five different fertiliser treatments were applied to 2 × 2 m plots (n = 4 plots per treatment), organised in a randomised design and separated by a 1 m wide buffer. These included: a no fertiliser control (C); undigested cattle slurry (US); the liquid fraction of anaerobically digested cow slurry (liquid digestate, LD); the dry fibre fraction of anaerobically digested cow slurry (dry fibre digestate, DFD); inorganic N 34.5% fertiliser (N; ammonium nitrate) and an inorganic NPK 21-8-11 (NPK) compound fertiliser (N in the form of both ammonium and nitrate; Yara (2017)). The US was collected fresh from an organic dairy farm (from lactating cows) and both digestates were collected from an AD unit on the same farm. The AD unit is a 1000 m^3 mesophilic (38 °C) gas mixing system, continually stirred digester with a retention time of 25 days and fed with cow slurry only. The system separates the digestate mechanically through a continuous belt press after leaving the digester, which enabled the liquid and solid fraction could be collected. Samples were refrigerated then analysed within 24 h of collection.

In all, six above-ground vegetation harvests were performed on the plots, with two harvests taken per year (May-June and August-September) to a height of 4 cm above the soil. Only the plant biomass within the central 1 m^2 of the plots was quantitatively evaluated, to avoid potential edge effects. To represent farmer practice, an initial application of 100 kg N ha^{-1} of each fertiliser type was surface-applied in mid-April, and the first harvest each year was undertaken six weeks later. A second fertiliser addition of 50 kg N ha^{-1} was then applied one week post-harvest (after some grass regrowth) and the final harvest taken six weeks thereafter. The application rate for each was normalised for nitrogen, based on total nitrogen content.

2.2 Soil, fertiliser and plant analysis

Soil samples were taken to a depth of 15 cm from each plot at the beginning of the experiment. Soil and organic fertiliser were extracted with 1 M KCl (1:5 (w/v)), shaken (250 rev min^{-1}, 1 h, 20 °C), centrifuged (4000 *g*, 15 min) and the supernatant filtered (Whatman no. 42) (Jones and Willett, 2006). Major cations (K^+, Na^+ and Ca^{2+}) were analysed using a model 410 flame photometer (Sherwood Scientific, Cambridge, UK), whilst NO_3^-, NH_4^+ and P were determined colorimetrically (Synergy® Microplate Reader; BioTek US, Winooski, VT) using the methods of Mulvaney (1996), Miranda et al. (2001) and Murphy and Riley (1962), respectively. Total organic carbon and nitrogen were measured using a CHN2000 elemental analyser (Leco Corp., St Joseph, MI), and dissolved organic carbon (DOC) and dissolved organic N (DON) were determined using a TCN-V analyser (Shimadzu Corp., Kyoto, Japan). Samples were oven dried at 105 °C for 24 h to determine gravimetric water content. Electrical conductivity (EC) and soil pH were determined using standard electrodes in 1:5 (w/v) distilled water extracts.

Forage digestibility was analysed from all treatments for the final two harvests (year three only). With the exception of the first harvest, the harvested material was manually separated to determine the proportion of grass and clover in the sward. All harvested plant material was weighed fresh, and then a 300 g subsample was removed, dried at 85 °C for 48 h, and reweighed. Crop nutrient analysis was undertaken using traditional wet chemistry (Givens et al., 2000) for both harvests in year three of the trial to determine total nitrogen content of the shoots. Digestibility was calculated using the modified acid-detergent fibre content of each sample (Givens et al., 2000).

2.3 Statistical analyses

Statistical analysis was performed using SPSS v.18 (IBM UK Ltd., Hampshire, UK). For analysis of crop yield data, total yield from all harvests were used and subject to a one-way ANOVA to determine differences within each sub-group, with treatment as the factor. The same analysis was used for nitrogen and digestibility tests. Post-hoc tests were carried out on all ANOVAs using Tukey HSD test at the level $p < 0.05$.

3. Results

3.1 Soil and fertiliser characterization

Table 1 reports the physico-chemical properties of the soil at the onset of the trial, and the mean of the three organic fertilisers used over the duration of the field trial. As both the feedstock used (cattle slurry) and the management of the digester remained constant throughout the trial period, there was comparatively little variability in the components of the digestate generated.

(Table 1 here)

3.2 Forage yields

The yield of grass obtained was slightly lower than typical values for a new pasture ley, although not so by year three of the study (AHDB, 2017). Yields were considerably greater in year three for all treatments and the control. The cumulative forage yield across all six harvests showed that plots applied liquid digestate (LD) had the greatest yield; indeed, yield was significantly greater ($p < 0.05$) compared to the straight inorganic N treatment, but not significantly different ($p > 0.05$) from pasture applied undigested slurry (US), digestate fibre (DFD) or NPK fertiliser. There was no significant difference between the two inorganic fertiliser treatments ($p > 0.05$).

(Figure 1 here)

3.3 Sward composition

Cumulatively over the three years' harvests, the unamended control had the greatest proportion of clover (of total yield), and was significantly greater ($p < 0.05$) from all other treatments (Table 2). Of the treatments, pasture applied US produced the greatest clover yield; although this difference was only significant ($p < 0.05$) to swards amended with inorganic N and not to any of the other organic amendments. There were no differences in clover percentage between pasture applied LD and DFD and that applied the two inorganic fertilisers ($p > 0.05$).

(Table 2 here)

3.4 Sward nitrogen content

Within ryegrass, all treatments had greater levels of nitrogen ($p < 0.05$) than control, but there were no differences between any of the other fertiliser treatments ($p > 0.05$); all being 28.8-35.2 g kg^{-1}. With respect to clover, the DFD treatment possessed the greatest amount of nitrogen of all treatments (mean of 48.2 g kg^{-1}), being significantly different from the inorganic N and NPK treatments, which possessed the lowest N levels (40.6-42.4; $p < 0.05$). Again, there was no statistical difference ($p > 0.05$) between the other treatments.

3.5 Forage digestibility

Grass applied LD had the lowest digestibility of all treatments at 60%, while all other treatments reported a value of 62-66%; however, none of these differences were statistically significant ($p > 0.05$).

4. Discussion

As well as being a source of renewable energy, anaerobic digestion is increasingly seen as a more sustainable way of recycling nutrients from wastes and by-products to land. However, surprisingly few studies have reported on the agronomic impacts of digestate application. The results presented here show that, cumulatively, application of organic fertilisers derived from anaerobic digestion gave similar yields of grass to when an NPK compound fertiliser were repeatedly applied over a three year period, and statistically greater yield than when straight N inorganic fertiliser was applied. Only a limited number of studies have compared the agronomic value of slurry-derived digestate relative to undigested slurry and inorganic fertiliser, and direct comparison of the results between studies is often difficult due to variability between feedstocks, the AD process (hence digestate properties), crops, and the rates and methods of digestate application (WRAP, 2016). Further, many such studies are based on pot trials set under controlled conditions (Möller and Müller, 2012) and only one growing season. In field trials over a longer harvesting period, the extra rooting volume of crops compared to pots may lead to the acquisition of mineralised organic nitrogen from manures by crops (Morris & Lathwell, 2004; Möller et al., 2008; Svensson et al., 2004). In this study, forage yield values increased with time, probably due to the third year being a wetter year than average for the area (data not shown) and hence facilitating growth. Further, there was no statistically significant difference from the application of undigested or digested slurry on forage yield over a three year period; which is in contrast with other studies mentioned previously. The variability in factors that govern growth with time reiterates the value in conducting trials over multiple years.

In comparison to straight ammonium nitrate inorganic fertiliser, organic fertilisers provide additional nutrients in the form of phosphorus and potassium; which may explain the lower yields from pasture applied the former in this trial (Figure 1). In the longer term, digestate application, relative to inorganic fertiliser may also increase soil organic matter and hence improve nutrient retention and overall soil quality, as well as provide residual effects due to the slower release of nutrients applied (Gutser et al., 2005). As expected, the nutrient profile of the separated (liquid and dry fibre) digestate components differed. Although it comes at some cost to the operator, separation of the digestate into the different fractions can therefore facilitate better targeting of nutrients according to crop and soil demands, in addition to reducing haulage and storage costs of dealing with all digestate as liquid.

Bougnom et al. (2012) reported greater percentage of legumes in soil treated with undigested manure rather than digestate, which corroborates our results (Table 2). Hakala et al. (2012) also reported that there was greater prevalence of clover plants (albeit insignificantly so) where organic fertiliser had been applied compared to inorganic fertiliser at the end of a three year field trial. The application of nitrogen is frequently reported to suppress clover growth, thereby reducing the beneficial supply of free nitrogen through N-fixation (Hakala et al., 2012; Nesheim et al., 1990). At the end of this study, control plots had the greatest percentage of clover, followed by pasture applied US, which were both statistically greater than all other fertilised treatments (Table 2). Thus, although digestate is an organic fertiliser, it may restrict clover growth over time in a similar way to inorganic fertiliser, possible due to the higher amount of plant-available nitrogen in digestate fertiliser compared to US (Walsh et al., 2012b). This may need further consideration given the dietary benefits to livestock of the presence of clover in grass swards and silage (Fraser et al., 2004).

Although converting foliar nitrogen content to leaf protein by multiplying by 6.25 tends to overestimate the true protein content of feedstocks, it is widely accepted as industry standard (Sriperm et al., 2011). After three years of fertiliser application, little difference in N/protein content was seen between all five fertiliser treatments. This is of note, as protein content is an important parameter of feed value, and the results indicate that other factors (e.g. fertiliser application rate, species of forage crop) have a greater bearing than fertiliser type on forage protein status.

Along with protein content, the feed value of grass is largely governed by the digestibility of the forage. In this study, no difference in relation to digestibility was reported between treatments. Digestibility of plant tissue typically increases with N fertilisation (Johnson et al., 2001; Messman et al., 1992; Prine & Burton, 1956). The fact that all harvest were taken within six weeks of fertiliser application, before any rapid decrease in digestibility, may explain the lack of treatment effect. It would be beneficial to have a longer harvesting time to determine if differences in digestibility would occur after an additional two-three weeks' growth.

5. Conclusion

Although this research was conducted on one crop and soil type and at one geographical location, it demonstrates the potential value of digestate as a nutrient source for pasture systems. Further, the study implies that application of digestate leads to a similar response in pasture yield as when a compound inorganic fertiliser is applied, and better than straight N organic fertiliser. Any agronomic benefits of replacing inorganic fertiliser use with digestate should be viewed alongside the long-term wider environmental benefits (e.g. in reducing GHG or loss of N to freshwater) and the potential value of digestate in raising soil organic matter levels.

Acknowledgements

We thank Llinos Hughes and Mark Hughes for help with the fieldwork. We gratefully acknowledge funding by the European Social Fund (ESF) Knowledge Economy Skills Scholarship through the European Union's Convergence Programme, administered by the Welsh Government, in association with Fre-Energy Ltd.

6. References

Bougnom, B.P., Niederkofler, C., Knapp, B.A., Stimpfl, E., Insam, H. 2012. Residues from renewable energy production: Their value for fertilizing pastures. *Biomass & Bioenergy*, **39**, 290-295.

Choudhary, M., Bailey, L.D., Grant, C.A. 1996. Review of the use of swine manure in crop production: Effects on yield and composition and on soil and water quality. *Waste Management & Research*, **14**(6), 581-595.

AHDB, 2017. *Nutrient Management – The Fertiliser Manual RB209*. Retrievable at http://www.ahdb.org.uk/projects/CropNutrition.aspx (accessed 25/1/17).

Demirer, G., Chen, S. 2005. Anaerobic digestion of dairy manure in a hybrid reactor with biogas recirculation. *World Journal of Microbiology and Biotechnology*, **21**(8), 1509-1514.

Ecoinvent, 2007. Ecoinvent data v2.0. in: *Ecoinvent reports No. 1-25*, Swiss centre for life Cycle Innventories. Dubendorf Switzerland.

Fraser, M.D., Speijers, M.H.M., Theobald, V.J., Fychan, R., Jones, R. 2004. Production performance and meat quality of grazing lambs finished on red clover, lucerne or perennial ryegrass swards. *Grass and Forage Science*, **59**, 345-356.

Givens, D.I., Owen, E., Axford, R.F.E., Omed, H.M. 2000. Forage evaluation in ruminant nutrition. CABI Publishing. ISBN: 0-85199-344-3.

Gutser, R., Ebertseder, Th., Weber, A., Schraml, M., Schmidhalter, U. 2005. Short-term and residual availability of nitrogen after long-term application of organic fertilizers on arable land. *Journal of Plant Nutrition and Soil Science*, **168**, 439-446.

Hakala, K., Nikunen, H.-M., Sinkko, T., Niemelainen, O. 2012. Yields and greenhouse gas emissions of cultivation of red clover-grass leys as assessed by LCA when fertilised with organic or mineral fertilisers. *Biomass & Bioenergy*, **46**, 111-124

Johnson, C.R., Reiling, B.A., Mislevy, P., Hall, M.B. 2001. Effects of nitrogen fertilization and harvest date on yield, digestibility, fiber, and protein fractions of tropical grasses. *Journal of Animal Science*, **79**(9), 2439-2448.

Jones, D.L., Willett, V.B. 2006. Experimental evaluation of methods to quantify dissolved organic nitrogen (DON) and dissolved organic carbon (DOC) in soil. *Soil Biology and Biochemistry*, **38**(5), 991-999.

Masse, D.I., Talbot, G., Gilbert, Y. 2011. On farm biogas production: A method to reduce GHG emissions and develop more sustainable livestock operations. *Animal Feed Science and Technology*, **166-67**, 436-445.

Messman, M.A., Weiss, W.P., Erickson, D.O. 1992. Effects of Nitrogen-Fertilization and maturity of Bromegrass on Nitrogen and amino-acid utilization by cows. *Journal of Animal Science*, **70**(2), 566-575.

Miranda, K.M., Espey, M.G., Wink, D.A. 2001. A rapid, simple spectrophotometric method for simultaneous detection of nitrate and nitrite. *Nitric Oxide-Biology and Chemistry*, **5**(1), 62-71.

Moeller, K., Schulz, R., Mueller, T. 2010. Substrate inputs, nutrient flows and nitrogen loss of two centralized biogas plants in southern Germany. *Nutrient Cycling in Agroecosystems*, **87**(2), 307-325.

Möller, K., Müller, T. 2012. Effects of anaerobic digestion on digestate nutrient availability and crop growth: A review. *Engineering in Life Sciences*, **12**, 242-257

Möller, K., Stinner, W., Deuker, A., Leithold, G. 2008. Effects of different manuring systems with and without biogas digestion on nitrogen cycle and crop yield in mixed organic dairy farming systems. *Nutrient Cycling in Agroecosystems*, **82**(3), 209-232.

Mulvaney, R.L. 1996. Nitrogen - inorganic forms. *In* Methods of Soil Analysis. Part 3. Chemical Methods (D.L. Sparks Ed.). SSSA, Madison, WI, USA, pp. 1123-1184.

Murphy, J., Riley, I.P. 1962. A modified single solution method for the determination of phosphate in natural waters. *Analytica Chimica ACTA,* **27**, 31-36

Nesheim, L., Boller, B.C., Lehmann, J., Walther, U. 1990. The effects of nitrogen in cattle slurry and mineral fertilizer on nitrogen-fixation by white clover. *Grass and Forage Science*, **45**(1), 91-97.

Prine, G.M., Burton, G.W. 1956. The effect of nitrogen rate and clipping frequency upon the yield, protein content and certain morphological characteristics of Coastal Bermudagrass (*Cynodon dactylon*, (L) Pers.). *Agronomy Journal*, **48**(7), 296-301.

Sriperm, N., Pesti, G.M., Tillman, P.B. 2011. Evaluation of the fixed nitrogen-to-protein (N:P) conversion factor (6.25) versus ingredient specific N:P conversion factors in feedstuffs. *Journal of the Science of Food and Agriculture*, **91**(7), 1182-1186.

Svensson, K., Odlare, M., Pell, M. 2004. The fertilizing effect of compost and biogas residues from source separated household waste. *Journal of Agricultural Science*, **142**, 461-467.

Walsh, J.J., Jones, D.L., Edwards-Jones, G., Williams, A.P. 2012a. Replacing inorganic fertilizer with anaerobic digestate may maintain agricultural productivity at less environmental cost. *Journal of Plant Nutrition and Soil Science*, **175**(6), 840-845.

Walsh, J.J., Rousk, J., Edwards-Jones, G., Jones, D.L., Williams, A.P. 2012b. Fungal and bacterial growth following the application of slurry and anaerobic digestate of livestock manure to temperate pasture soils. *Biology and Fertility of Soils*, **48**(8), 889-897.

WRAP (Waste & Resources Action Programme). 2016. Field experiments for quality digestate and compost in agriculture: DC-Agri research summary. Retrievable at http://www.wrap.org.uk/sites/files/wrap/WRAP_DC-Agri_research_summary.pdf (accessed 11/8/2017).

Yara, 2017. *YaraMila – Compound Fertiliser*. Retrievable at http://www.yara.co.uk/crop-nutrition/fertiliser/compound/ (accessed 10/8/17).

Figure 1: Annual dry matter (DM) grass yield over the three-year field trial, following the application of different fertiliser types: no-fertiliser control (C), undigested slurry (US), liquid digestate (LD), dry fibre digestate (DFD), inorganic fertiliser (N) and compound inorganic NPK fertiliser (NPK). Values represent means ± SEM (*n* = 4).

Table 1: Mean physico-chemical properties of the soil and of the organic fertilisers (undigested slurry (US), liquid digestate (LD) and dry fibre digestate (DFD)) used over the three-year field trial. Values represent means ± SEM (*n* = 9) and are expressed in terms of dry weight, where applicable.

		Organic fertiliser		
	Soil	US	LD	DFD
pH	5.45 ± 0.02	7.07 ± 0.24	8.44 ± 0.12	8.89 ± 0.13
EC (mS cm^{-1})	44.4 ± 5.4	5.68 ± 1.68	6.57 ± 2.82	8.12 ± 6.05
Dry matter (%)	78.3 ± 0.2	14.4 ± 1.6	4.9 ± 1.6	24.3 ± 1.4
Total C (mg g^{-1})	ND	393 ± 8	214 ± 6	289 ± 8
Total N (mg g^{-1})	ND	30.2 ± 5.4	66.4 ± 4.9	38.4 ± 6.4
C-to-N ratio	–	27.7	10.2	34.4
DOC (mg g^{-1})	0.1 ± 0.0	58.2 ± 13.0	47.2 ± 14.9	29.2 ± 5.7
DON (mg g^{-1})	ND	13.2 ± 0.9	27.3 ± 4.9	10.1 ± 1.8
NO_3^- – N (mg g^{-1})	<0.1	0.44 ± 0.07	0.35 ± 0.08	4.24 ± 4.01
NH_4^+ – N (mg g^{-1})	<0.1	15.39 ± 4.68	38.55 ± 5.14	23.58 ± 0.23
P (mg g^{-1})	0.09 ± 0.01	11.70 ± 2.29	3.69 ± 1.42	6.16 ± 1.08
K (mg g^{-1})	0.03 ± 0.01	12.53 ± 3.33	13.41 ± 1.95	12.73 ± 3.85
Ca (mg g^{-1})	0.04 ± 0.01	10.50 ± 3.90	8.30 ± 5.60	2.30 ± 0.60
Na (mg g^{-1})	0.07 ± 0.01	2.86 ± 0.85	8.12 ± 3.06	7.80 ± 1.40

ND: not determined

Table 2: Percentage of clover in the yield of forage harvested over the three-year field trial, following the application of different fertiliser types (Control received no fertiliser). Letters denote significant differences between treatments ($p < 0.05$).

Treatment	Clover (% of DM yield)
Control	34.9^{a}
Undigested slurry	29.4^{b}
Liquid digestate	$22.1^{b\ c}$
Dry fibre digestate	$22.1^{b\ c}$
N inorganic fertiliser	22.2^{c}
NPK compound inorganic fertiliser	21.6^{c}