

Teagasc Open Day at Johnstown Castle
Environment Research Centre, Wexford

Slurry and nutrient efficiency display



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AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

Slurry and nutrient efficiency display

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THE DEPARTMENT OF
AGRICULTURE, FISHERIES & FOOD
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National Development Plan 2007 - 2013

Teagasc Open Day at Johnstown Castle
Environment Research Centre, Wexford

Thursday, 1st May 2008

Welcome

On behalf of Teagasc, I welcome you to Johnstown Castle today.

Our Slurry and Nutrient Efficiency Open Day today will demonstrate some new techniques that are emerging to facilitate the spreading of slurry. New thinking is also emerging on getting more value from the nitrogen in slurry by changing the times of spreading.

Fertilizer prices have rocketed this year. The price of nitrogen, phosphorus and potash are such that care must be taken with every kg of fertilizer spread. One of the principal ways of reducing fertilizer bills is to use slurry effectively. One thousand gallons of slurry is now worth approximately €25. In addition to saving money, the effective use of slurry can lead to reduced emissions of ammonia to the air that in turn leads to less odours and better air quality.

Today is an ideal opportunity to learn first hand about the ongoing research at Teagasc Environment Research Centre. While the focus of today's event is on slurry application, we also have information available on our other research programmes including biodiversity, nutrient efficiency, soils, and water quality. To complement the information on display today, our event booklet provides interesting back-up to today's technical programme.

Finally, much of the research work being presented today on slurry application is co-funded by the Department of Agriculture, Fisheries and Food Research Stimulus Fund (2005) under the National Development Plan. I gratefully acknowledge this funding.

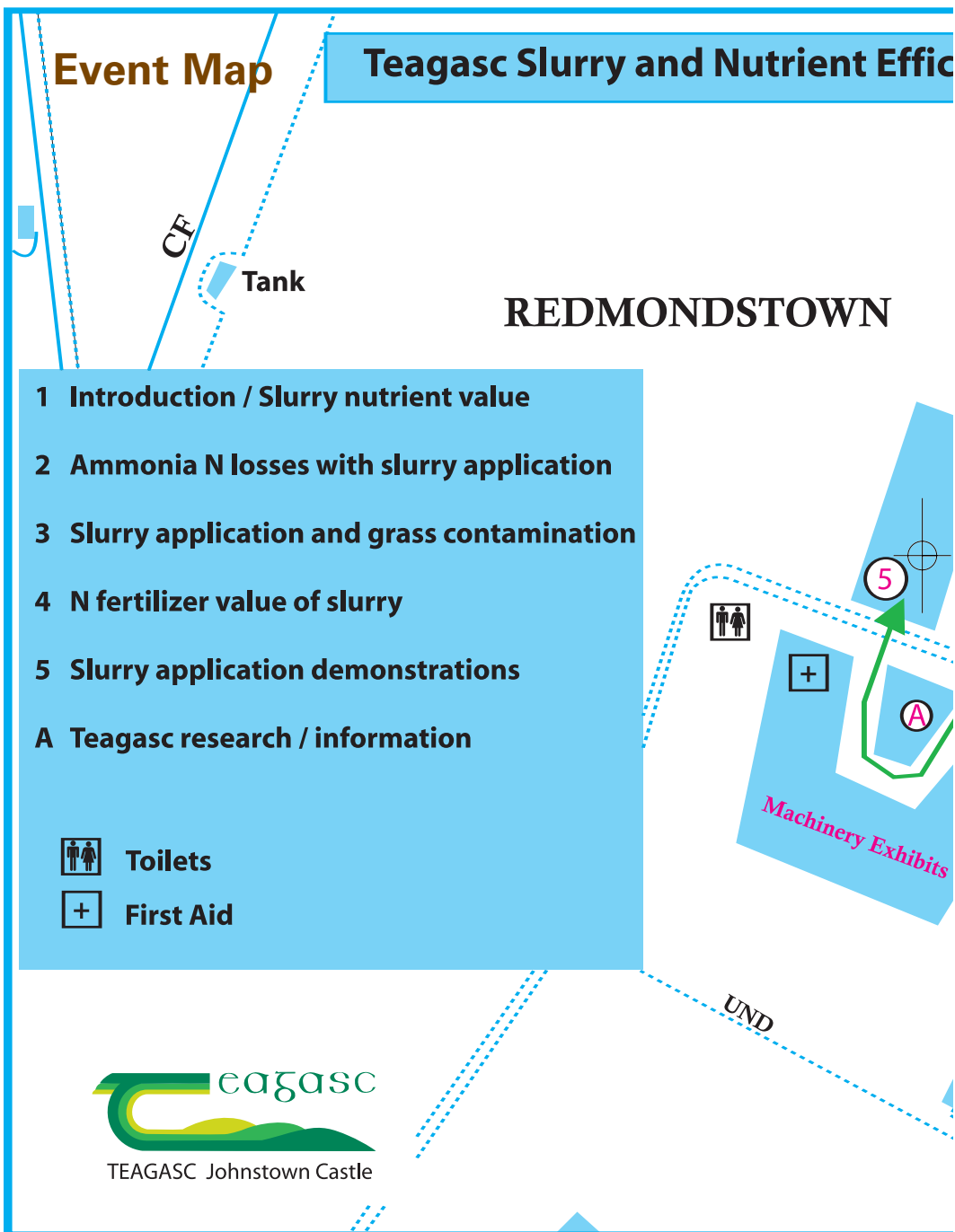


Head of Centre



Dr Noel Cullen
Head, Teagasc,
Johnstown Castle
Environment Research
Centre, Wexford

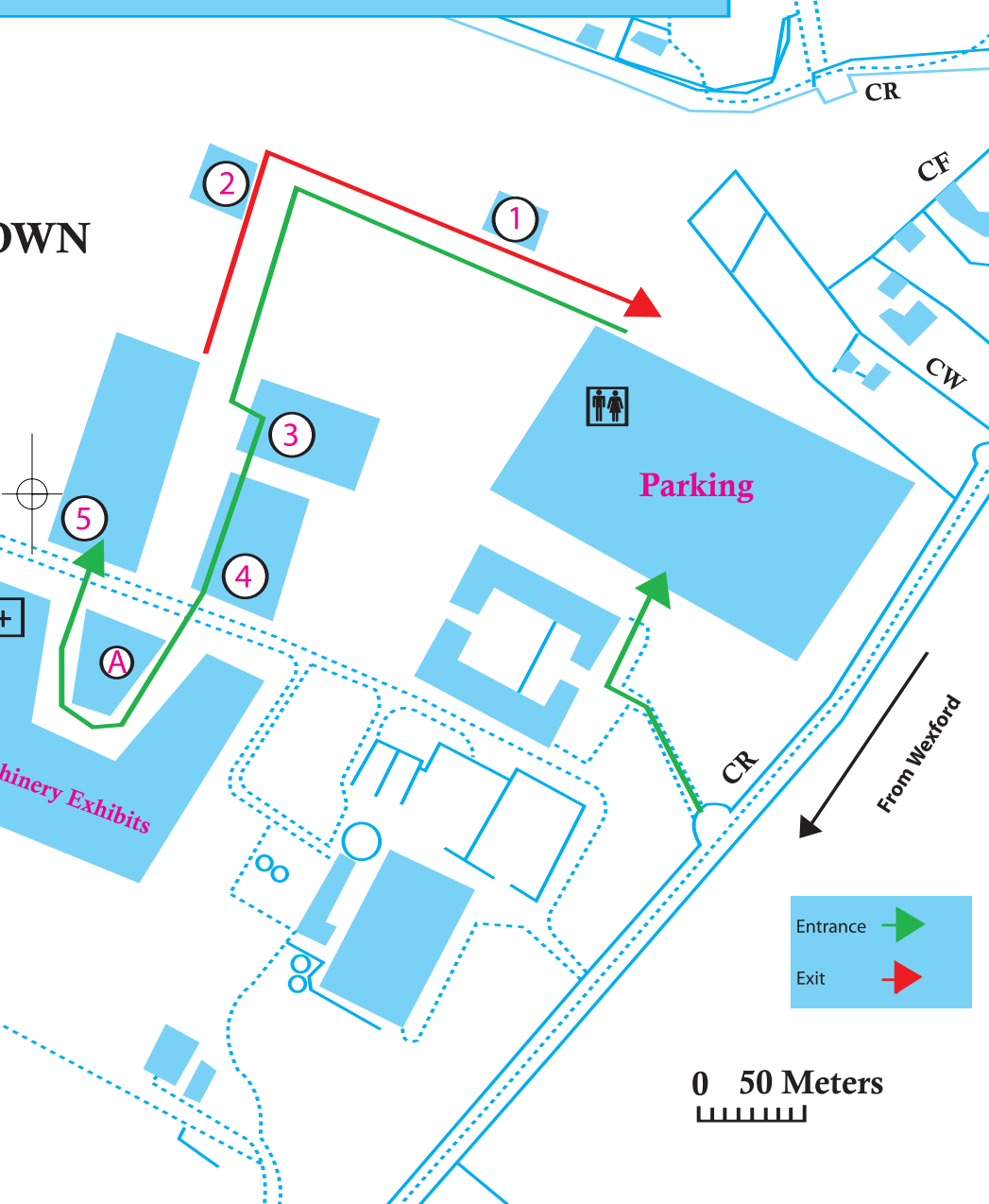
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Slurry and nutrient efficiency display

Putting a value on cattle slurry – getting the most from P and K

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Fertilizer prices have almost doubled in the last eight months and all indications are that prices will remain high over the coming years. As a result, cattle slurry is becoming increasingly valuable as a source of fertilizer nitrogen (N), phosphorus (P) and potassium (K) on farms.

In addition to the increase in fertilizer prices, the regulation controlling the application of N and P fertilizers has resulted in many farms not being allowed any chemical P fertilizer on the farm. This situation is most common on farms that have a proportion of land with soil test P in the Index 4 range, or where high levels of concentrate feeds are being used. On farms where no chemical P fertilizer is allowed, cattle slurry is the only form of manageable P fertilizer that will be available to the farmer to apply P to the areas of the farm that have a P requirement. Therefore, careful consideration should be given to what areas should receive cattle slurry, and to the application rates at which they are applied.

Fertilizer value

The fertilizer value of cattle slurry in terms of nutrient supply can be variable due to the nature of slurry. One thousand gallons can potentially replace one 50 kg bag of 10-6-38. In money terms, this is worth approximately €25. The P content is mostly contained within the solid fraction; the K in slurry is in the liquid fraction (from urine); and the N tends to be divided equally between the solid fraction and the liquid fraction.

Maximise savings – P and K

A large proportion of the total economic value of slurry is attributable to the P and K content, which can be worth approximately €22 of the total value. However, this economic value can only be transferred into a cost saving if the chemical fertilizer costs can be reduced by applying slurry.

Each area of the farm will have its own specific requirement for P and K fertilizer. This requirement is normally determined by two factors. First, the land use will be important e.g., the P and K requirements for a silage crop are normally higher than that of pasture that is only grazed. Also, the stocking rate of grazed pasture will affect the amount of P and K fertilizer that is required. Second, the soil test results will also determine the P and K requirements of each part of the farm. Soils with lower soils test P and K levels will have higher requirements for P and K fertilizers.

To reduce fertilizer costs, slurry should be applied to areas that have a P and K

requirement. If slurry is applied to fields that have no P or K requirement while other parts of the farm continue to receive chemical P and K fertilizer, the result is no savings in fertilizer costs. Occasionally in the past, slurry may have been applied to fields that were more convenient to the farmyard and slurry storage tanks in order to minimise slurry spreading costs.

As the value of slurry rises due to increased fertilizer prices, the distribution of slurry around the farm to fully maximise its fertilizer value is worth re-examining. This may be particularly relevant on out-farms that might have high P and K requirements, often deemed too far away to justify slurry transport costs. An increase in the value of slurry of up to €22 per 1,000 gallons may go a long way towards off-setting the increase spreading cost associated with taking the slurry to land that is further from the farmyard.



Potential savings from slurry application can only be realised when chemical fertilizer applications are reduced to account for slurry nutrients.

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The effect of application technique and climate conditions on ammonia emissions from cattle slurry

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Under the National Emissions Ceilings Directive (2001), Ireland is limited to produce 116,000t of ammonia (NH₃) come 2010. Whilst Ireland is currently compliant with emissions below this target at 113,000 kT, future targets are likely to be more restrictive. Almost 98% of national emissions are attributed to agriculture, with the land spreading of cattle manure accounting for 47% of this total. Since approximately 80% of all cattle manure in Ireland is produced as slurry, there is an interest in slurry spreading methods that will reduce ammonia emissions.

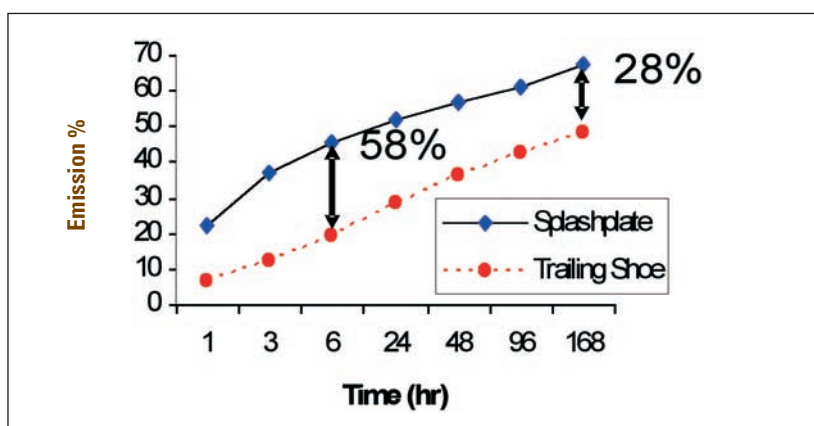
Low-emission spreading technologies have been shown to reduce emissions by up to 95% compared with the conventional splashplate or broadcast application method (*Misselbrook et al. 2002*). The trailing shoe is of particular interest in Ireland not only because of its potential to reduce NH₃ emissions but also its potential to extend the spreading window, by allowing placement of slurry below a high grass canopy rather than on top of it.

There are numerous factors which can affect the rate and total emissions of ammonia from slurry. These include the dry matter (DM), and total ammonium nitrogen (TAN) content of the slurry itself. Slurry with a high concentration of TAN has the capacity to emit more ammonia than slurry with a lower concentration. Changes in dry matter content will influence the rate of slurry infiltration into the soil, thus affecting the duration of time for which the slurry exposed to the prevailing weather conditions. Weather conditions can have a large effect on the rate of ammonia emissions, with factors such as high wind speeds, high solar radiation, high soil/air temperatures, and low rainfall, promoting a high rate of ammonia volatilisation. Soil conditions such as moisture content can also have an effect, as a dry soil will lead to faster infiltration of the slurry and therefore lower emissions (*Sommer and Hutchings 2001*).

To investigate the effect of application technique and climate on ammonia emissions, cattle slurry (dry matter - 8.3%; total ammoniacal nitrogen (TAN) - 1.7 kg/t) was applied at 30t/ha to circular grassland plots (30 m diameter), using either the trailing shoe or splashplate methods. The grassland was a first-cut silage pasture located at Johnstown Castle. Ammonia emissions were measured using passive flux samplers or 'shuttles' which were coated in acid to trap ammonia.

On average, the ammonia emissions were lower using the trailing shoe (Figure 1). Six hours after slurry application, ammonia emissions were 58% lower with trailing shoe compared with splashplate application. However, because the trailing shoe applies slurry in lines/bands it dried out more slowly and emitted ammonia over a longer period. Therefore, a week after application, the emission reductions delivered by trailing shoe had decreased to 28.4% (Figure 1).

Figure 1: Ammonia emissions as a percentage of total ammonium N (TAN) applied using both splashplate and trailing shoe techniques.



The percentage reduction in total ammonia emissions delivered by the trailing shoe compared with splashplate also varied with the timing of application. In May, during sunny days, with high temperatures and windspeed, the trailing shoe reduced emissions by over 47% compared with splashplate (Figure 2). By contrast, April application, on days when conditions favoured low ammonia volatilisation (cloudy days with some rain), there was no significant difference in application method on emissions (Figure 2),(overpage).

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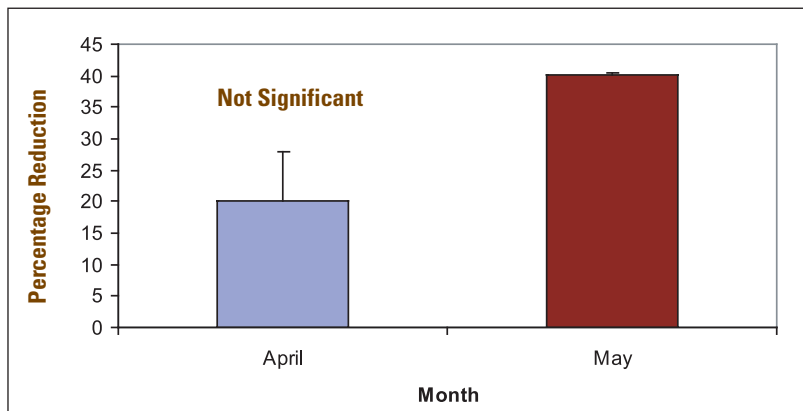


Figure 2: The percentage reduction in ammonia emissions between trailing shoe and splashplate during April and May.

Conclusion

There was a significant reduction in the amount of ammonia volatilised by the trailing shoe application compared with the splashplate, but only under conditions promoting high levels of volatilisation. While the trailing shoe has the potential to reduce ammonia losses under certain weather conditions, splashplate application that is targeted towards optimal weather conditions, for minimising ammonia losses, can also be an effective approach to reducing N losses to the air from slurry application.

Nitrogen fertilizer replacement value of cattle slurry applied to grassland

S. Lalor and R. Schulte

Teagasc, Johnstown Castle Environment Research Centre, Wexford

Up to now, Teagasc advice relating to nitrogen (N) efficiency with cattle slurry application to grassland has been based primarily on application timing. Cattle slurry applied in spring was considered to have an N fertilizer replacement value (NFRV) of 25%. This means that 1kg of slurry N could replace the 0.25kg of chemical N fertilizer. Slurry applied in summer was considered to have a lower NFRV of 5%.

Nitrogen in slurry

The total N content in cattle slurry is highly variable, but studies show that cattle slurry will contain, on average, 3.6 kg/t of total N. However, only approximately 50% of this total N content is present in a form that can be taken up immediately by plants. This form of N is called ammonium-N. The remaining 50% is present in the solid portion of the slurry. This N may be released over time, but the process is gradual and may take many years.

While the ammonium-N is available to plants, it can also be lost to the air as ammonia gas. Therefore, the NFRV of cattle slurry will depend on how the cattle slurry is applied so that the losses on ammonia to the air can be minimised.

Ammonia loss to the air

Losses of N as ammonia to the air are highest in dry, windy, warm, sunny weather conditions. Any day that could be called 'a good drying day' could also be considered as a day when ammonia N losses from slurry would be high. Days that are dull, overcast, calm, and cool are ideal for slurry application. Light mist or drizzle is also ideal, although heavy rain should be avoided to reduce risks of nutrient loss.

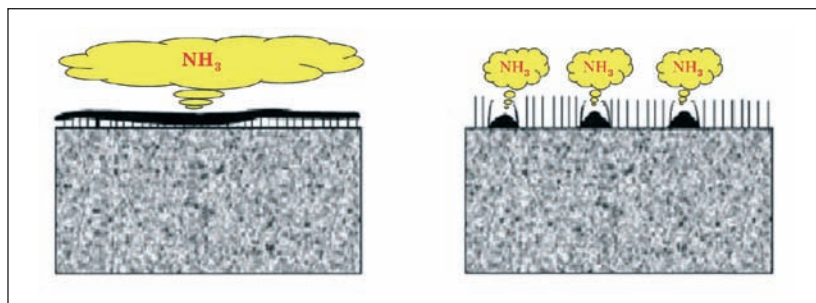
Spring application is favoured over summer application as favourable weather conditions are normally more common in spring than summer. However, this is not exclusively the case, therefore, weather conditions at the time of slurry application should be considered irrespective of what time of year the application is occurring at. Late autumn and winter applications also tend to have reduced N losses to the air, but grass growth rates at this time are also low, resulting in reduced uptake of N by the grass.

Application method

Reducing the losses of ammonia-N to the air can also be achieved by varying the slurry application method. Low emission application methods such as bandspreader, trailing shoe, and shallow injection tend to have lower losses of ammonia to the air. This is because they apply slurry in lines, thereby reducing the surface area of slurry exposed to the weather, and reducing the potential for ammonia volatilisation as a result (**Figure 1**)

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Figure 1. Low emission methods (shown on right) reduce the surface area of slurry exposed for loss of ammonia (NH_3) to the air compared with splashplate application (shown on left).



Research work in Teagasc

Current Teagasc advice assumes relatively low NFRV percentages for slurry, and research abroad (e.g., UK, Denmark, Holland) shows improvements have been made possible through the adoption of low-emission application methods. In light of this, Teagasc began a three-year research programme in 2006 to examine if the NFRV of cattle slurry to grassland could be improved.

This project will continue until 2009. Some results from field trials carried out to date are presented here.

Overview of field trials

Field trials are being conducted at three sites; in Cork (well-drained), Wexford (moderately-drained), and Clare (poorly-drained). The effect of application timing (February vs. April vs. June), and the application method on the NFRV of cattle slurry applied to grassland are being examined. Grass yield was harvested six to seven weeks after slurry or fertilizer application. Nitrogen fertilizer was applied to separate plots to establish the grass DM yield response to N fertilizer. The mean DM yield obtained from the slurry-treated plots were then compared to the fertilizer N response curve to calculate the NFRV of the slurry applications.

The results of all the experiments conducted to date (June 2006 to February 2008) are shown in Table 1.

Table 1. Summary of NFRV% observed from slurry application at various application timings with splashplate and trailing shoe application methods.

Application timing	No. of experiments	NFRV % observed		Mean NFRV %
		splashplate	trailing shoe	
February	1	11	12	12
April	2	29 (27-30)	39 (39-40)	34
June	5	10 (5-14)	21 (11-39)	15

The results in Table 1 show that the assumed differential between spring (April) and summer (June) application is correct. However, further analysis will be required to collate the weather conditions at the time of application with the NFRV observed with each experiment. Also, the variability of NFRVs observed is higher with summer application. However, this is to be expected as to date more experiments have been conducted at the summer application timing.

The difference between splashplate and trailing shoe application shows that for both April and June applications, the NFRV with trailing shoe application is 10-11 percentage points higher than the NFRV with splashplate application.

The results from the February application of slurry were surprisingly low. This application timing was generally considered to be equal to April application in terms of expected NFRV. The results in Table 1 suggest that this is not the case. It must be noted however, that these results are for one experiment only. This will be repeated in February 2009 to give more information. Possible explanations for the low NFRV observed are the poor grass growth conditions observed in Spring 2008. Also, soil compaction associated with slurry application in early spring may be impacting on subsequent growth potential.

Reducing chemical fertilizer N

To translate the NFRV values observed into potential fertilizer savings, it is useful to consider the value of 11t/ha (1,000 gals/acre) of slurry relative to chemical N fertilizer (see Table 2).

Table 2. Typical N fertilizer value of an 11 t/ha (1,000 gallons/acre) application of cattle slurry with a typical total N content of 3.6 kg/t, based on the results obtained in experiments to date.

N fertilizer value of 11 t/ha (1000 gallons/acre) of slurry				
	splashplate		trailing shoe	
	kg/ha	units/acre	kg/ha	units/acre
February	4.4	3.5	4.8	3.8
April	11.5	9.2	15.4	12.4
June	4.0	3.2	8.3	6.7

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Conclusion

Based on experiment results to date, the current assumption that slurry NFRV is higher with spring application is correct. With conventional splashplate application, the NFRV was, on average, 29% in April, and 10% in June.

The experiment examining February application showed a lower than expected NFRV value. However, it is necessary to repeat this experiment in 2009 to make definitive judgements on the NFRV with slurry application in February.

Slurry application using trailing shoe increased the NFRV compared to splashplate application in both April and June. However, the NFRV in April with either application method was higher than the NFRV with trailing shoe in summer.



Slurry applied in April (after closing for first-cut silage) showed higher NFRV than slurry applied in June (after silage harvest)

Limitations to spring application of cattle slurry to grassland in Ireland

S. Lalor and R. Schulte

Teagasc, Johnstown Castle Environment Research Centre, Co. Wexford.

Spring application (i.e., between February and early May) is currently viewed as the optimum application time in order to maximise the nitrogen fertilizer replacement value (NFRV) of cattle slurry applied to grassland in Ireland. Current agronomic advice assumes that the NFRV of cattle slurry is 25% if applied in spring, whereas the NFRV is only 5% if applied in summer. Despite this, approximately 50% of cattle slurry is applied in the summer period. Soil conditions (trafficability and pollution risk) and the fear of grass contamination affecting subsequent herbage quality are seen as the main restrictions to spring application. Described below are some results of a study that examined the extent to which each of these constraints limits spring application of cattle slurry to grassland for contrasting soils and locations.

Overview of study

The soil moisture model of *Schulte et al. (2005)* and grass growth data were used to calculate daily soil moisture deficits (SMD) and grass covers for six hypothetical farms with varying meteorological and soil drainage characteristics for an eight-year period (1998-2005 inclusive). Three of these hypothetical farms (one well-drained, one moderately-drained, and one poorly-drained) were based on grass growth data from Teagasc, Ballyhaise, and weather data from Clones. Another three farms (one of each soil drainage class) were based on grass growth data from Teagasc, Moorepark, and weather data from Cork Airport.

Grassland management regimes appropriate to each soil type, as per milk production blueprints for poorly- and free-draining soils, were applied to establish the grass cover pattern over the whole farm for the period 1 January to 10 May for each year.

Three parameters were included as indicators of the suitability of each day for slurry application:

- 1) The minimum time lag before subsequent drainage or overland flow was set at two days to minimise the possibility of pollution occurring;
- 2) A minimum SMD threshold of 10 mm was set as an estimate of soil suitability for damage-free traffic; and,
- 3) Grass contamination was minimised by setting a minimum requirement of 42 days before subsequent grazing or harvest event. Application was allowed within this threshold. The effect of varying this maximum threshold was examined.

The model determined a day as being available for slurry application if a minimum of 20% of the farm satisfied these criteria. The maximum grass cover thresholds compared were 300, 600 and 900 kg/ha dry matter (DM). Grass covers refer to DM above 4cm.

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Results and Discussion

The effect of the selected maximum grass cover thresholds on the median number of days per year on which 20% or more of each farm was available for slurry application between 1 January and 10 May is shown in **Figure 1**.

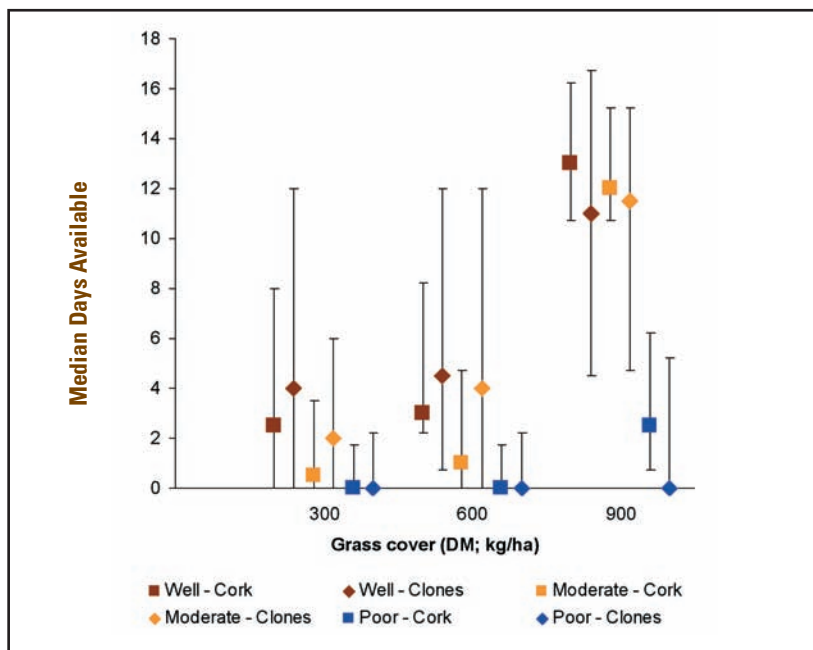


Figure 1. Effect of minimum grass cover threshold on the median number of days with $\geq 20\%$ of the farm available for slurry application between 12 Jan and 10 May. (Bars indicate variability in results between the eight years).

On well- and moderately-drained soils, the median number of available days increased by between 7 and 11 days per year when the maximum grass DM cover threshold was increased from 300 to 900 kg/ha. While the number of available days was also higher with the 600 kg/ha maximum compared to 300 kg/ha, the difference was smaller, ranging from an increase of 0.5 to 2 days per year. On these soils, an application method that would allow contamination-free slurry application to grass cover approaching 900 kg/ha would increase the window of opportunity for spring application.

On poorly-drained soils, there was no effect of increasing grass cover on available days, suggesting that soil trafficability is the greatest limiting factor on such soils.

Conclusions

Based on the soil trafficability indicator used in this study, soil trafficability is the main restriction of spring application. Slurry application methods that can reduce soil compaction and increase soil trafficability, such as the umbilical slurry application system, would increase the opportunity for spring application.

On well- and moderately-drained soils, methodologies that allow application in swards with higher grass covers, such as the low-emission application methods (bandspreader, trailing shoe, and shallow injection), also increase the opportunity for spring application. This is due to the fact that a greater area of the farm would be available for slurry application on days when soil conditions are suitable, as the restriction imposed by the consideration of grass cover on each field would be reduced.



Grass contamination can be reduced with low emission application methods compared to splashplate, as the slurry is applied in lines/bands. This allows slurry to be applied into taller grass swards, and increases the opportunity for slurry application in spring.

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Comparing slurry application methods - alternatives to splashplate tankers

S. Lalor

Teagasc, Johnstown Castle Environment Research Centre, Wexford

Umbilical systems

The umbilical slurry application system requires two tractors. One tractor operates a pump situated at the slurry storage tank. This pump sends slurry via a flexible pipe to an application unit (operated by the second tractor) in the field. Umbilical systems help reduce soil compaction, as heavy tankers full of slurry are not required. Slurry can be pumped to distances of up to 1km or more. Umbilical systems can be fitted with either splashplate or low-emission application units.



Band spreading

The bandspreader is the simplest low-emission method, and can be used in both grassland and arable crops. The slurry is deposited by pipes that are situated above the crop. The ammonia losses and sward contamination compared to splashplate are reduced as the slurry is deposited in lines.



Trailing hose

The trailing hose method is similar to the bandspreader, except that instead of the pipes depositing slurry above the canopy, they are longer and trail along the ground. This allows slurry to be applied directly at the soil surface. The trailing hose is commonly used for applying slurry to cereal crops after sowing, as wide booms are available to facilitate travelling on tramlines.



Trailing shoe

The trailing shoe is an adaptation of the bandspreader whereby each pipe has a 'shoe' coulter attached at the base of the pipe. These shoes separate the sward canopy and apply slurry at the soil surface. The advantage of this application method is that sward contamination, compared to the splashplate in particular, is minimised, thereby facilitating application to taller grass swards with minimal effects on grass quality due to herbage contamination. Opportunity for spring application to grassland may be increased as a result.



Shallow injection

The shallow injection method has discs that cut slits into the soil. The slurry is then placed into these slits. This is the best method for reducing ammonia losses, as the exposure of slurry to the weather is minimal because the slurry is applied directly into the soil. However, shallow injection may not be suitable to all Irish soils due to the soil variability of texture, stone content and topography. The shallow injection method also requires greater tractor power to pull the injection unit through the soil.



Efficient and reliable utilisation of nutrients in animal manure: fate of slurry N in grassland

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Introduction

Approximately 50% of nitrogen in slurry is in organic form and needs to be mineralised in the soil before it becomes available for plant uptake, resulting in the so called residual effect of slurry. Currently, due to insufficient data, this residual effect is not accounted for when determining slurry nutrient utilisation. This project uses a combination of conventional agronomic techniques and ¹⁵N stable isotope labelling methods to investigate the fate of organic and inorganic slurry nitrogen in the soil-plant system. ¹⁵N isotope labelling involves the addition of an enriched form of nitrogen to slurry; this acts as a chemical tracer so that the pathway of N can be traced in grass and soil pools.

Experiment 1: Labelled slurry ammonium-N

The objective of this experiment is to determine slurry ammonium N recovery in herbage and soil in the year of application as affected by application method (splashplate/trailing shoe); application time (spring/summer); and grass height (low/high). A small quantity of highly enriched (98% ¹⁵N) ammonium is added to the ammonium fraction of slurry and then applied to small grassland plots. Slurry was applied in lines (to simulate trailing shoe application) or across plots (to simulate splashplate application). The proportion of slurry ammonium ¹⁵N uptake in grass and the soil pools throughout the growing season and the proportion lost from the plant-soil system can then be estimated.

Experiment 2: Labelled slurry N-fractions

The objective of this experiment is to trace the fate of different slurry (organic) N fractions in plant and multiple soil layers up to two years after application. Artificial slurries were made up by mixing dung and urine collected from cows which had been fed different diets containing ¹⁵N. Two labelling methods were used. In method one, ¹⁵N-labelled urea was sprinkled over the grass forage fed to a dry cow, and the dung and urine were collected separately for a number of days. This resulted in ¹⁵N-labelled urine and partially labelled dung. For method two, a dry cow was fed ¹⁵N-labelled grass forage (grown with ¹⁵N-labelled fertilizer), resulting in ¹⁵N enrichment of all the dung and urine fractions. Dung and urine were then proportionally recombined to make up four different slurries with a DM content of approximately 7%, and applied to grassland plots and soil cores in June 2007. The fate of N released from the slurry will be measured in seven harvests through to September 2008.

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Expected outcomes

Preliminary measurements show that the labelling of the dung using the two methods resulted in a sufficiently high ^{15}N enrichment of the dung (1-2% enriched, as expected). When the first results of the N enrichment of grass and soil fractions are available, it will be possible to calculate the fate of the different slurry N fractions throughout the plant-soil interface over time. This will provide new information on the pattern of availability of slurry N, both in the short and longer term, and assist with improving nutrient efficiency on farms.



a) trailing shoe



b) Splashplate

Micro-plots used for Experiment 1 following application of slurry using different simulated methods.



Research is underway to investigate the release of the residual N from the organic N fraction of slurry on grassland.

Exploiting pig manure as a nutrient source for cereals in Ireland

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Traditionally, a considerable proportion of the pig manure was applied to grassland. However, the implementation of nutrient loading restrictions associated with SI 378 will restrict the amount of grassland available to pig producers for application of their manure. This leaves the pig producer with a considerable dilemma – what to do with his manure. Using pig manure as a nutrient source for arable crops is a potential solution to this dilemma that also provides benefits to the arable producer in that his chemical fertilizer costs can be reduced. This is of particular interest to arable growers at a time of increasing fertilizer prices.

Pig manure can have a highly variable nutrient content and to achieve maximum benefit growers should know the nutrient content of the particular batch of manure being used. There are relatively inexpensive, rapid, easy-to-use, on-farm methods to determine nitrogen and phosphorus content of manure.



Slurry can be applied to growing cereal crops with the trailing hose application method. This application method can be fitted with wide booms that allow machinery to travel along the crop tramlines.

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A potential deterrent to using manure as a nutrient source is that the amount of chemical fertilizer that can be applied to a crop must be reduced where pig manure is applied. Arable growers must, therefore, be confident that the pig manure will supply the required amount of nutrients to counteract the reduction in fertilizer, before utilising the manure. Current research at Oak Park focuses on determining the nutrient value of pig manure for spring barley with particular attention being focused on the nitrogen value of the manure. Initial results, which corroborate research from abroad, indicate that pig manure can effectively replace a portion of the chemical nitrogen fertilizer requirement of the spring barley crop, provided the manure is incorporated soon after application. Pig manure can also be applied to growing winter crops but requires specialised equipment, not yet abundant in Ireland, for best results.



National proximity analysis of tillage spread-lands and large pig enterprises

Réamonn Fealy

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Due to the cost of hauling and applying manure, accessibility to suitable spread-lands is a key issue in the area of manure management. There are varying opinions on whether the enterprises producing significant quantities of manure are within economic distance of suitable spread-lands or not, with a generally argued belief that they are not. The national distribution of pig enterprises places many of these production units close to tillage land, which is considered potentially suitable for spreading. However, a comprehensive analysis has not been completed to describe this national distribution or the spatial relationships with available spread-lands. A thorough economic assessment of the most appropriate regime for manure management needs to account for the distance/transport cost variable.

This spatial assessment of the enterprise spread-lands relationship will provide a critical input to the formal assessment of the nature of the associated distance-cost equation and can provide the primary input to an economic assessment of the role of off-farm transportation in manure management strategies. The development of this analysis will also provide a baseline dataset that can be used to model the economic impacts of different manure management strategies under varied policy initiatives.

While the required software procedures are complex, the concept underlying network-based distance analysis is simple. Essentially, a network analysis results in actual, real journey distances as opposed to straight-line calculated distance. Real journey distance will almost always be greater than straight-line distance. This is principally due to the effects of topography as road layout must accommodate slope, shape and altitude changes of the natural landscape. In many cases due the cost and complexity of network analysis software and the unavailability of road network data, straight-line distances are the normal method of assessment. Resulting in an underestimate of the resources and costs required to complete the assessed journeys.

A key strength of the work presented here is that it will provide the first comprehensive analysis of the spatial relationship between major pig-producing enterprises and potential tillage spread-lands. In the context of an increasingly challenging environment for pig producers, due to regulatory and legislative developments arising from the Nitrates Directive and an increasingly competitive market place, the results from this work will provide a solid baseline for an economic assessment of the impact of these and other market developments. This will provide key supporting data which will inform the future strategic development of the pig industry in Ireland.

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Notes