Crops
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Programme

Soil Fertility Conference 2016

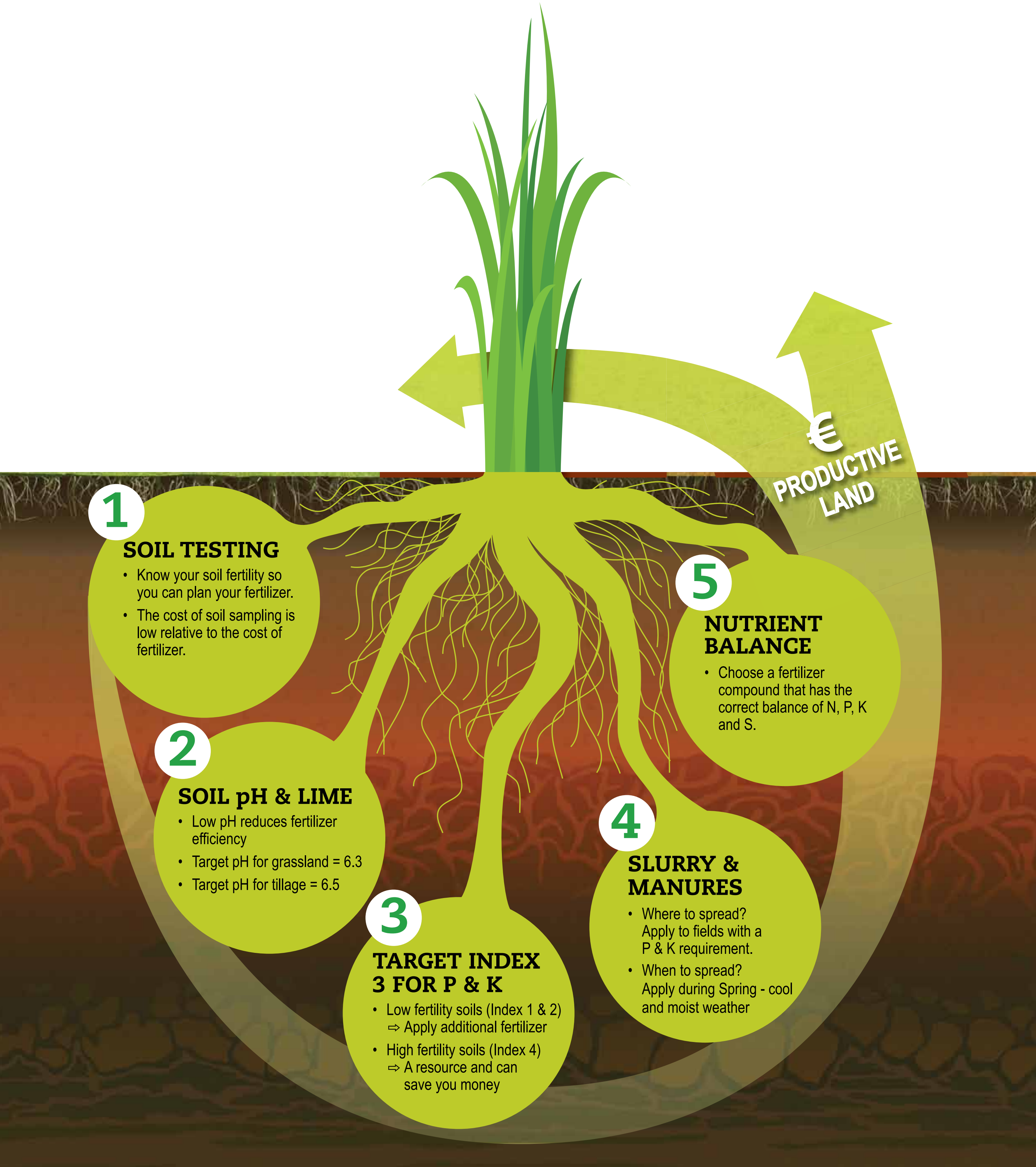
‘Efficient fertilizer use for tillage crops’

Teagasc

Agriculture and Food Development Authority

SOIL FERTILITY

THE KEY TO GROWING YOUR PROFIT



Soil Fertility Conference 2016
'Efficient Fertilizer Use for Tillage Crops'

AGRICULTURE AND FOOD DEVELOPMENT AUTHORITY

Maximising farm productivity and profitability through efficient use of fertilisers for tillage crop production

Launch of Teagasc "Green Book"
Major and Micro Nutrient Advice for Productive Agricultural Crops

Lyrath Hotel, Kilkenny, Co. Kilkenny
Wednesday, 19th October 2016
10.00 am to 4.00pm

Edited by David Wall, Mark Plunkett and Patrick Forrestal
Teagasc, CELUP, Johnstown Castle, Co Wexford

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Soil Fertility Conference 2016
Efficient use of fertilizers for tillage crop production

Introduction

Teagasc welcomes you today to this event as part of the national soil fertility campaign. The theme of this event is maximising farm productivity and profitability through the efficient use of manures and fertilizers for tillage crop production.

Irish tillage soils are amongst the most productive in the world, especially for cereal grain production. Good productive soils are the foundation of any successful farming system and key for achieving high crop yield and quality, some of the main drivers of tillage farm profitability. Good soil fertility is also required to exploit the high yield potential of new crop varieties and to overcome yield stagnation, a feature of modern crop production. Adequate crop nutrition is also critical in combating crop pests and diseases which are prevalent in our mild humid climate. For efficient nutrient uptake good soil structure is essential, where crops can establish vigorous root systems, to deliver daily water and nutrient requirements of the crop throughout the growing season. Protecting soil structure is becoming more challenging on many tillage farms due to the slow decline in quality of soil organic matter over time and reduced opportunities to conduct tillage operations when soil conditions are favourable during prolonged periods of inclement weather.
Building soil quality and soil fertility takes time and is often compromised due to short term land management as operated by our con-acre system. Fertilizers account for approximately one third of variable crop production costs on an annual basis. In this current period of low grain prices, planning effective nutrient management strategies according to expected crop yield targets is essential to remain profitable. Developing a planned and balanced approach to soil fertility on a field by field basis through tailored lime, manure and major and minor fertilizer nutrient inputs is a good starting point. Therefore, the management of soil fertility and soil quality levels should be a primary objective on every tillage farm.

Soil fertility Management

Now is the time for farmers to make decisions regarding lime, manure and fertilizer management strategies for their farms. The continued price cost squeeze in crop production and the large proportion of land farmed on a short term letting agreement has led to decreasing trends in national soil fertility. A recent review of soils tested at Teagasc indicates that the majority of soils (85%) in Ireland are below the target levels for pH (i.e. 6.5) or P and K (i.e. Index 3) and will be very responsive to application of lime, P & K. On many farms sub-optimal soil fertility will lead to a drop in output and income if allowed to continue. The starting point is to complete a farm fertilizer plan to guide lime, fertilizer / manure decisions in 2017 and to avoid further decline in soil fertility levels.

During this Soil Fertility Conference Teagasc is highlighting 5 steps for effective soil fertility management:

1) Have soil analysis results for the whole farm.
2) Apply lime as required to increase soil pH up to target pH for the crop.
3) Aim to have soil test P and K in the target Index 3 in all fields.
4) Use organic fertilizers as efficiently as possible.
5) Make sure the fertilizers used are properly balanced.

The main focus of this event is to highlight and discuss issues related to good soil fertility management for maximising the productivity of our soils. For those farmers aiming to improve soil fertility on their farms, following these 5 steps provides a solid basis for success.

Programme Soil Fertility Conference 2016

9.15: Coffee on arrival

Programme Soil Fertility Conference 2016

12.30 – 13.45: Lunch

Potassium and Barley Production

Mark Plunkett[1], Martin Bourke[2], Patrick Forrestal[1], & David P. Wall[1]

[1]Teagasc, Johnstown Castle, Co. Wexford, [2]Teagasc, Office, Tinahely, Wicklow

Summary

- High yielding barley crops have a high demand for potassium during the growing season
- Very low (Index 1) soil potassium (K) levels will constrain grain yield potential
- Muriate of potash is an effective source of K for barley crops
- Potassium has a role in protecting the plant from powdery mildew infection
- Straw brackling decreased as K rate increased towards the optimum level for yield

Introduction

Potassium (K) is a key nutrient in the production of high yielding barley crops. However, limited research work on K has been conducted in recent years, with the primary focus on efficient crop use of nitrogen (N) and phosphorus (P) to meet environmental targets. Potassium plays many key roles in the plant and aides plant stress tolerance mechanisms, increases straw strength and efficient use of N to name just a few. With higher yielding crops there is a larger demand for K to support crop development during the growing season. In recent years the following questions have been asked. What are the K requirements of modern high yielding barley crops? Are these crops removing more soil K compared to older varieties? Is there a difference between types of K fertilizer (MOP v SOP)?

Effect of Soil K on Grain Yield Potential

In general Irish soils tend to have good levels of soil K due in part to native K reserves in many Irish soil types. However, in 2015 approximately 44% of tillage soils were low in K (10% of tillage soils were very low (Index 1), 34% low (Index 2). Low soil K levels, especially at Index 1, will limit crop yield potential as soil K supply is likely to be inadequate for prolonged periods, especially at key growth phases when the components of crop yield are being laid down. For example, optimum tiller number development for spring cereals or rapid canopy expansion during stem extension for winter cereals. Recent field trials on K for spring and winter barely will be discussed in this paper. At Oak Park, Co. Carlow a K trial on spring barley in 2015 showed the effect of very low and low soil K status (Index 1 and 2) on response to applied K fertilizer and grain yield (Figure 1).

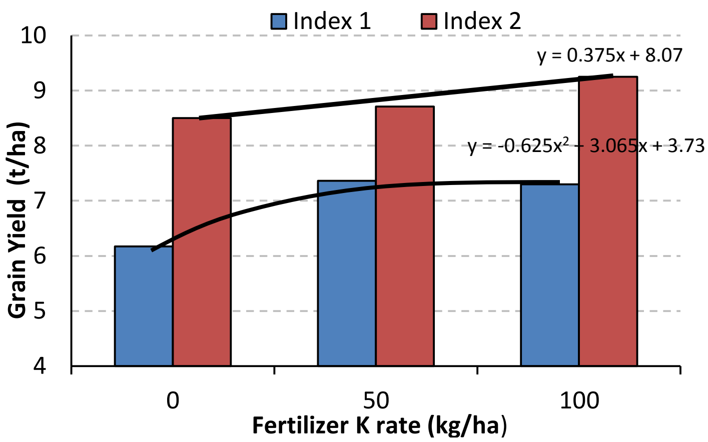

Figure 1. Spring barley grain yield response (t/ha) to fertilizer K application rate (kg/ha) for K Index 1 & K Index 2 soils at Oak Park, Co Carlow in 2015.

Without fertilizer K application the Index 1 (48 mg/l) soil yielded 6.2 t/ha while the index 2 (79 mg/l) soil yielded 8.5 t/ha. This shows the importance of higher soil K status for grain yield potential. Potassium fertilizer was applied as MOP (50% K) after crop emergence at GS 12. An application of 50kg K/ha on the Index 1 soil increased grain yield by 1.2 t/ha over the control, however, there was not further yield response to fertilizer K application of 100kg/ha. This highlights the important role of supplying sufficient K early to meet crop requirements in the establishment phase. On the Index 2 soil there was a grain yield response 0.75 t/ha up to 100kg/ha K applied, indicating higher responses in the index 2 soil due to its higher yield potential. These results for spring barley indicate that the higher soil K confers higher grain yield potential which cannot be recovered with in-season fertilizer applications.

In 2016 a winter barley K response trial was conducted on medium textured soil in Arklow, Co. Wicklow, evaluating responses in 2-row (cv. Cassia) and 6-row (cv. Meridian) barley cultivars separately in the same field. The soil K levels at the site were Index 2 (2-row site = 95mg/l & 6-row site = 71mg/l). Two sources of K fertilizer were evaluated; muriate of potash (MOP) and sulphate of potash (SOP). Figure 2 shows the grain yield response to six fertilizer K application rates ranging from 0 to 200kg K/ha. Overall the 6-row had higher yield potential and yielded on average 2.1 t/ha above the 2-row barley. As K rate increased from 0 to 200kg/ha grain yield increased by 0.97 t/ha and 0.7 t/ha for 2- and 6-row barley types, respectively. Each 1.0 t/ha grain yield removed 10kg K/t, therefore the 6-row barley removed an additional 21 kg/ha K over the 2 row variety. This shows that fertilizer programmes need to be adjusted to take account of K removed at harvest time to maintain soil K fertility within the optimum range.

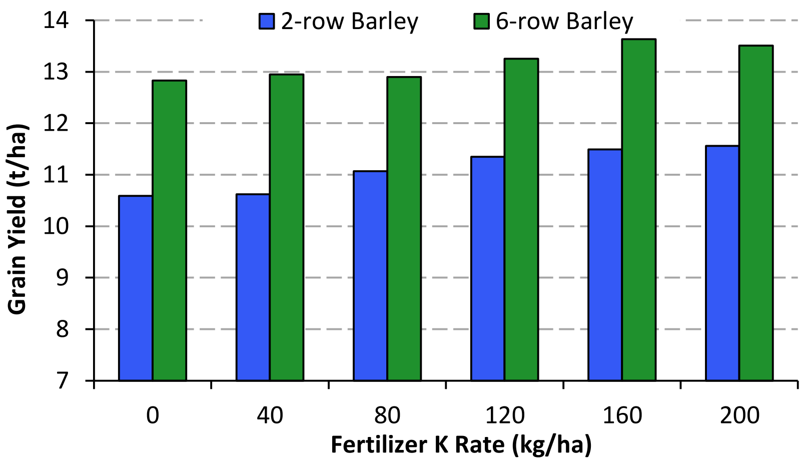

Figure 2. Winter barley grain yield response (t/ha) to fertilizer K application rates (kg/ha) for 2 & 6 row winter barley varieties at Arklow, Co. Wicklow in 2016

Effect of K on disease control

In both the spring and winter barley, with zero K application (i.e. control plots) high levels of powdery mildew was present from flag leaf to ear emergence compared to plots where K was applied. This demonstrates the role of K in protecting the plant from disease infection such as powdery mildew. As the rate of fertilizer K increased the level of brackling decreased with each incremental increase in K rate up to 160 kg/ha K.

Fertilizer Type – MOP v SOP

Muriate of potash is the most widely used source of K fertilizer in Ireland, with SOP usually used for high value crops such as vegetables. There has been much discussion on the merits of SOP vs. MOP for barley crops. Both MOP and SOP were applied to the 2-row and 6-row winter barleys. The MOP produced significantly higher grain yield compared to SOP for the 6-row barley, but there was no significant difference for the 2-row barley. On sites known to respond to S applications, SOP, which supplies 18% S, may achieve high yields than MOP. Research has shown that MOP treated barley crops are more effective at protecting against powdery mildew and may explain why the MOP tended to produce higher yields (significantly higher in the 6 row barley) compared to the SOP treated plots.

Improving soil organic carbon in tillage systems: the overlooked nutrient

Gary Lanigan & Richie Hackett

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Summary

- Soil organic matter (SOM) / soil organic carbon (SOC) levels in arable systems are lower compared to grassland and forest systems due to ploughing and fallow periods
- Improving SOM will increase aggregate stability, reduce susceptibility to compaction, erosion and nutrient leaching as well as increasing soil fertility by improving nutrient availability
- Furthermore, carbon sequestration associated with SOM build-up will offset greenhouse gas emissions

Introduction

Soil organic matter forms due to the decomposition of plant and animal residues that enter the soil system. These inputs include leaf and straw residues, root material, soil biota and any applied animal manure. Soil organic carbon (SOC) is the main constituent of SOM, accounting for over 50% of the total and sequestration of carbon in soils plays a vital role in removing CO_2 from the atmosphere. Indeed global soils contain 2,200 billion tonnes of carbon, three times the amount in the atmosphere. Soil organic matter is also rich in nutrients such as nitrogen (N), phosphorus (P), sulphur (S), and micronutrients and SOM increases have been directly and positively related to soil fertility and agricultural productivity potential. SOM/SOC consists of an active labile pool which is readily available to soil organisms and a passive recalcitrant pool (humus) that is hard to decompose. Sequestration occurs when there is a build-up in the passive pool while the labile pool is most associated with the nutrient effects of SOM.

Role of soil organic matter in crop productivity

The role of soil organic matter in enhancing productivity can be classified into three broad categories: biological, physical, and chemical. SOM contributes to soil nutrient retention by increasing the cation exchange capacity (CEC) which determines a soil's ability to retain positively charged plant nutrients. Thus, SOM can act like a slow release fertilizer. SOM also plays a key role in soil aggregate formation which reduces soil bulk density and compaction. As a result, it increases the soil water holding capacity. SOM provides an energy source for soil microbes and fauna. These are vital for decomposition and soil nutrient cycling.

Impact of Tillage on SOM and SOC

Cropland soils generally store less SOC than grazing land because cropland has greater disturbance from cultivation, a lack of organic manure being returned to the system, has a winter fallow period and as a consequence, has less root and shoot material returned to the soil. Changes in SOM/SOC are not linear and reach a new equilibrium over time (Figure 1). In other words, accumulation of SOM is finite.

When some aspect of management changes, the SOC will begin to change, initially at a relatively fast pace for the first 20-50 years but thereafter at a declining pace until a new equilibrium is reached, usually after about 100 years. After this time continuation of the particular management practice leads to no further changes in SOC.

However, if the management practice ceases to be used SOC levels will not remain at the equilibrium level but will begin to return to its original level, often more rapidly than it was accumulated. Therefore any management practice adopted to increase SOC must be continued indefinitely in order to maintain the benefit of that practice.

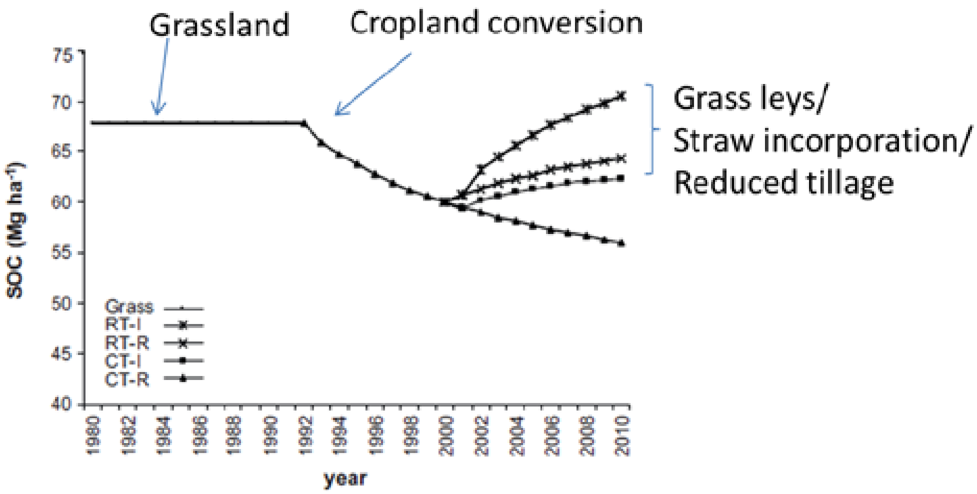

Figure 1. Impact of grassland conversion to cropland and subsequent impact of management on soil organic carbon. (From van Groenigen et al. 2011 *Ag Ecosyst. Environ.*).

Management options to increase SOM/SOC

Cover crops/rotations:

Crop rotations that include cover crops, perennial grasses and legumes maximize soil C inputs and maintain a high proportion of active C. Cover crops are slow to increase the total SOM/SOC levels, but increase the active pools quicker.

Straw and manure incorporation:

Straw incorporation increases SOC as organic matter is directly inputted back into the soil. Figure 1 shows that for every tonne of straw incorporated per hectare, a 7-17% increase in SOC (top 15 cm only) was observed (depending on whether reduced tillage was also applied). Manure inputs will also build SOC stocks, particularly FYM.

Reduced/minimum tillage:

The concept of reduced tillage is that aggregates are disrupted less leading to reduced SOC loss. However, while SOC levels in the top 30cm are increased, there is increasing evidence that ploughing may simply redistribute SOC over a greater depth profile and when looked at over a full soil profile, to say 1m depth, often no difference is observed between ploughing and reduced tillage.

Conclusion

Increases in SOC as a result of management changes are slow and reversible and management needs to be tailored to individual circumstances. Indeed, soil carbon and soil organic matter is easily lost but difficult to rebuild. However, proper management is central to both agricultural productivity, and other ecosystem services, such as tackling climate change.

How does urea and protected urea compare to CAN for spring barley production?

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K.G. Richards[1], L.J. Shaw[3], D.P. Wall[1]
[1]Teagasc, Crops Environment and Land Use Programme, Johnstown Castle, Wexford.
[2]Teagasc, Crops Research Centre, Oak Park, Carlow, [3]University of Reading.

Summary

- Protected urea fertilizers [urea with N-(n-butyl) thiophosphoric trimide (NBPT)] are now available in Ireland and are an alternative N fertilizer source to CAN
- In 2016 the urea products with NBPT that were available were KAN , AGRHO N Protect B and Eco-COAT.
- Where urea is used, variable ammonia N losses can occur depending on weather conditions, but when urea is protected by NBPT this is not a concern
- Emissions of nitrous oxide, a potent greenhouse gas, from spring barley were low regardless of the N fertilizer used
- Spring barley grain yields were similar regardless of N fertilizer used
- Overall protected urea has similar yield, greater crop N recovery and is cheaper per unit of N than CAN

Introduction

CAN is the dominant N source used by tillage farmers in Ireland but contributes to environmental losses of N including gaseous emissions of nitrous oxide (N_2O) and nitrate (NO_3^-) leaching. Replacing CAN with urea could reduce these N losses but there is potential for increased N loss through ammonia (NH_3) volatilisation. Using urea protected with the urease inhibitor NBPT can protect against NH_3 loss and produce yields similar to CAN.

Recent research

In order to evaluate the performance of protected urea a field experiment was conducted on a free-draining loam soil cropped with spring barley in Marshalstown, Co. Wexford between 2013 and 2015. Grain Yield and N uptake were measured over three years and gaseous emissions and nitrate leaching were measured over two years. The fertilizers evaluated were CAN, urea and protected urea (urea + urease inhibitor NBPT). The protected urea product used in these trials contained NBPT at 660 ppm. An unfertilised control was also included. The N fertilizer rate used was 150 kg/ha and this was applied in two splits. The first split was 30 kg/ha applied at sowing and the remaining 120 kg/ha was applied at mid-tillering. The crop was sown in April each year and was harvested in late August.

Grain yield and fertilizer N recovery

Grain yields were similar regardless of the N fertilizer used but N uptake was higher with protected urea (Figure 1) compared to CAN. Of the 150 kg/ha N fertilizer applied, the N uptake was on average approximately 13 kg/ha higher from the protected urea compared to CAN over the 3 years. In this study urea and CAN produced similar yields but there should be caution when using urea as yields can be variable and other studies have shown reduced yields using urea compared to CAN due to ammonia (NH_3) volatilisation.

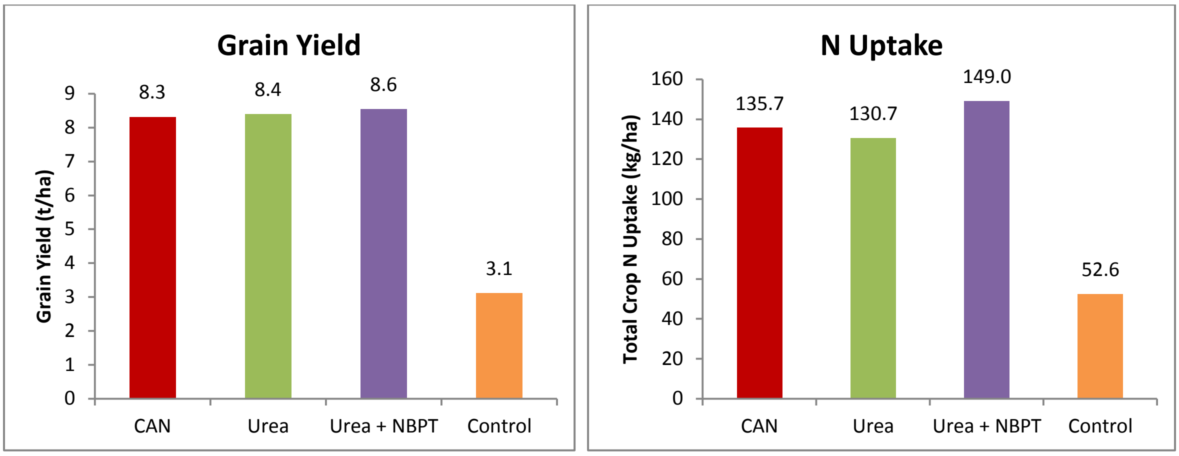

Figure 1. Grain yield and N uptake from different fertilizers across three years

Gaseous emissions and N balance

Gaseous emissions of nitrous oxide were similar regardless of the N fertilizer used. Ammonia losses were increased with urea but were similar to CAN when protected urea was used. A relative star rating for each fertilizer product incorporating gaseous losses and yield is shown in Table 1.

Table 1. Relative star rating of CAN, urea and protected urea incorporating yield and losses

	CAN	**Urea**	**Protected Urea**
Cost of N	★★★½	★★★★★	★★★★
Yield	★★★★★	★★★★	★★★★★
N Uptake	★★★★★½	★★★★	★★★★★
Nitrous oxide	★★★★	★★★★	★★★★
Ammonia	★★★★	★★	★★★½
Leaching	★★	★★★★	***Not available**

Conclusions

This study showed similar yields between CAN and urea. However, it must be borne in mind that other studies have found reduced yields using urea due to ammonia volatilisation. Using protected urea reduced N (ammonia NH_3) losses compared to urea and consistently produced similar yields to CAN with slightly higher N uptake. Using protected urea also reduced nitrous oxide (N_2O) emissions. Overall using urea protected with NBPT you can be confident of producing at least the same spring barley yields as could be achieved using CAN with potential cost and environmental benefits.

Nitrogen management in winter barley

Richie Hackett

Teagasc, Crops Environment and Land Use Programme, Oak Park, Carlow

Summary

- Maintaining high tiller number is important in barley and nitrogen has an important role in tiller survival
- Applying first N in mid-March gave similar yields compared to late February/early March, for crops that reached GS30 in late March/early April, indicating flexibility regarding when the first N can be applied
- Applying a high proportion of the total (<30%) in the first application was not beneficial for yield
- Generally there was no difference between using two or three splits in terms of yield
- Generally no effects of timing or size of first N application on hectolitre, except occasionally where first N was delayed until late March/early April.
- Where phosphorus is being applied with the nitrogen early application is advised, particularly where soil phosphorus levels are low

Introduction

Until recently it was recommended that nitrogen be applied to winter barley in Ireland in two applications with the first being applied at the late tillering stage, just as the crop was about to enter stem extension and the remainder at around GS31. In terms how much to apply in the first application the advice has been that 25-30% of the total was sufficient. This advice was largely based on extensive research work carried out in the seventies and eighties. There has been relatively little recent work, under Irish conditions, regarding timing of N for winter barley. However, recent work in the UK advocates earlier application of N to winter barley than was previously recommended. In addition it is advised to have at least 50% of N applied before stem extension. This has led to increased interest in timing of N to winter barley. This paper reports on experiments examining the effect of different fertilizer N application timings to winter barley and the effects of applying different proportions of the total fertilizer N in the first application.

Experimental details

A series of experiments were carried out between 2012 and 2015 at Oak Park. In each experiment three timings (early, mid and late) of the initial application of fertilizer nitrogen were examined. First N was applied to the 'early', 'mid' and 'late' treatments in late February or early March, mid-March and late March/early April, respectively. In the trials GS30 occurred in late March or very early April, so for the early and mid-treatments the first N application was applied before GS 30, with the late treatment applied between GS30 and GS31. In addition to timings, the experiments compared treatments where different proportions of the total amount of N (30%, 50% and 70%) were applied in the first application. A total of 180 kg N/ha was applied in each experiment as CAN. Phosphorus, potassium and sulphur were applied independently of nitrogen according to recommendations. Experiments were carried out principally on a light textured sandy soil that had been cultivated for >20 years. In two seasons (2014 and 2015) a medium textured soil was used. Winter barley (cv. Cassia) plots were sown in late September or early October.

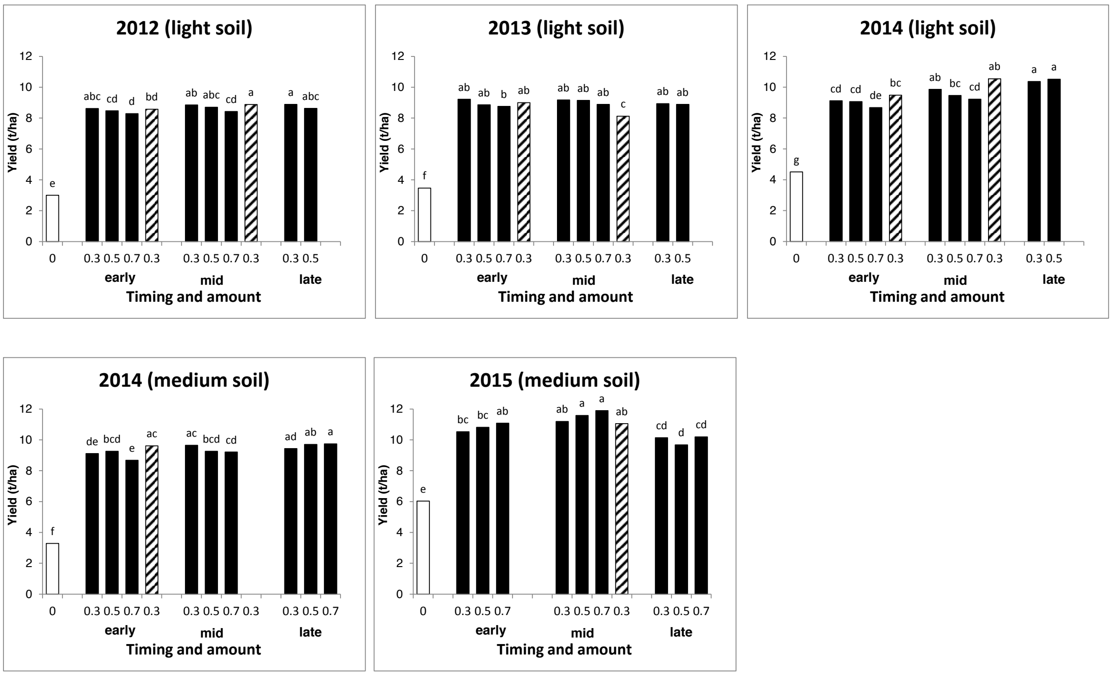

Figure 1. Effect of timing and size of the first N application (30 – 70% of total N) to winter barley (cv. Cassia). Total N was applied in two (solid bars) or three (hatched bars) applications in late February/early March (early), mid-March (mid) or late March/early April (late). Bars with the same letter are not significantly different ($P<0.05$).

Yield differences between the ‘early’ and ‘mid’ treatments were generally small and not statistically significant with any differences that did occur being in favour of the mid-March timing (‘the mid treatment’). Surprisingly, even where the first N application was delayed until late March/early April yield was significantly reduced in only one season. However, this late treatment tended to result in late maturing tillers, particularly where the proportion applied in the first application was small. Hectolitre weight was generally not affected by timing of the initial dose, except in some seasons where the late timing gave small reductions. Increasing the proportion of the total applied in the first application tended to give reductions in yield, albeit often not statistically significant, in each experiment except in 2015. Effects of using three splits, where 20% of the total was applied at flag leaf emergence/early booting, compared to two splits were usually small and variable with, on average, no benefit accruing.

Conclusion

The results of these trials would indicate that the timing of the initial dose of N is not critical to winter barley yield as long as the first N is applied by around GS30. This gives growers flexibility regarding timing of the initial dose, particularly where soil conditions are not suitable for application in late February or early March. However it should be noted that in these experiments other nutrients were applied independently of nitrogen. Where other nutrients, particularly phosphorus, are being applied with the first N application the first application should be applied before mid-March to ensure timely application of the phosphorus. In terms of the proportion applied in the first application there was no benefit to applying more than 30% of the total and in some cases applying more than 30% resulted in reduced yields. Differences in yield between two splits and three splits were relatively small.

Evaluating soil structural quality and compaction

Eileen Jeuken[1], Cait Coyle[1] and Owen Fenton[2]

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[2] Teagasc, Crops Environment and Land Use Programme, Johnstown Castle, Wexford

Summary

- Soil structure influences the delivery of soil functions, including primary production (grass or tillage crops)
- Soil structural quality and compaction can be evaluated using visual soil evaluation (VSE) techniques
- GrassVESS is an example of VSE technique suitable for Irish soils which has been developed specifically for grassland to evaluate management impacts on soil structural quality
- An independent evaluation study of the GrassVESS technique is currently being conducted as part of the Soil Quality Research (SQUARE) Project

Introduction

Soil structure determines the ability of a soil to provide the five key agronomic functions of; (1) primary productivity (grass or tillage crops), (2) water purification (3) carbon sequestration, (4) habitats for biodiversity and (5) nutrient cycling. Good soil structural quality (small friable round aggregates) enhances the delivery of soil functions, while poor soil structural quality (large compact angular/ sub angular aggregates) can undermine their delivery. Land Management practices can impact on the structural quality of a soil and cause compaction, with high soil moisture status (wet soil conditions) increasing a soils vulnerability to land management induced compaction forces. In grassland livestock and machinery can cause compaction; surface compaction can occur due to poaching (hooves) of livestock at high stocking densities while subsurface compaction can occur due to heavy machinery used for operations such as slurry spreading.

The structural quality of a soil can be evaluated directly in the field using visual soil evaluation (VSE) techniques. An example of a VSE technique for use on Irish soils is the GrassVESS technique, which has been developed by Booth *et al*. (2016), to evaluate the impacts of land management on the structural quality of grassland soils. GrassVESS is a 'spade' VSE technique which assesses the structural quality of the top 25cm of a grassland soil. The technique takes a user approximately 10 – 15 minutes to conduct utilising simple hand tools, e.g. a garden spade, to express the soil structural quality as a soil structure score (1 – 4) and a root mat score (1 – 3); lower scores reflect a good soil structural quality while the higher scores reflect a poor soil structural quality.

Evaluating the GrassVESS technique

An independent evaluation study of the GrassVESS technique is being conducted as part of the Soil Quality Research (SQUARE) Project in order to evaluate the; (1) accuracy, (2) reliability, and (3) influence of soil moisture and soil texture on the technique. As part of this evaluation study during the summer of 2016 the GrassVESS technique was assessed on 20 grassland sites across Ireland in order to evaluate the (1) temporal and seasonal reliability, (2) accuracy against the laboratory measurable soil property for compaction (bulk density), and (3) influence of soil moisture and soil texture on the results. Although the evaluation results of this 20 site study are currently undergoing analysis, the soil structural quality of the 20 sites has been released.

Soil structural quality of 20 grassland sites assessed using the GrassVESS technique

The GrassVESS technique was conducted on 'typical' areas with no visible soil structural damage, and 'a-typical' areas with visible soil structural damage, which was possibly caused by livestock or machinery around water troughs/feed troughs/ gateways of each site. The soil structural quality for each site (Table 1) indicate that overall, the typical areas reflect better soil structural quality compared to atypical areas; soil structure scores (Figure 1) and root mat scores (Figure 2) for 'typical' areas reflected lower values comparison to 'a-typical' areas.

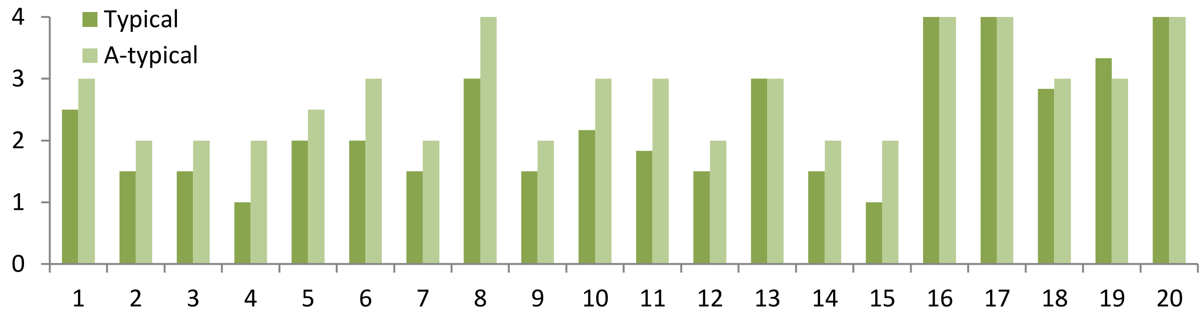

Figure 1. GrassVESS Soil structure scores of 'typical' and 'a-typical' areas of the 20 Irish grassland sites.

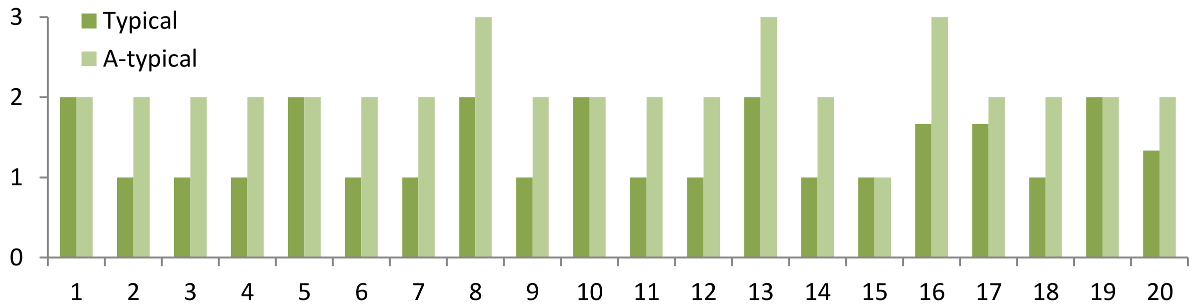

Figure 2: GrassVESS Root mat scores at 'typical' and 'a-typical' areas of the 20 Irish grassland sites.

Conclusion

Although the evaluation study of the GrassVESS technique is currently still in progress, the soil structural quality for the 20 grassland sites evaluated using the GrassVESS technique indicate that; areas with no visible soil structural damage show more favourable soil structural quality in comparison to areas with visible soil structural damage i.e. around water troughs/ feed troughs or gateways, thus suggesting that the GrassVESS technique can provide an indication of grassland management impacts resulting from livestock or machinery induced compaction on the structural quality of Irish grassland soils.

Soil testing: what it does and where is it going

Karen Daly

Teagasc, Crops Environment and Land Use Programme, Johnstown Castle, Wexford.

Summary

- Soil testing is an essential part of soil fertility and nutrient management
- Conventional tests for nutrients such as phosphorus (P) use chemical reagents to extract a small portion of P in soil to predict plant available P
- Research has shown that soil properties such as pH, organic matter and clay minerals (Al, Fe and Ca) affect P availability and interact with chemical tests
- New techniques in soil sensing are being developed that capture multiple soil properties, without the need for chemical extractions, and have applications for portable analysis

Introduction

Chemical tests for soil were developed in the 1940's to measure the amount of nutrients that plants could access. These tests were calibrated with growth trials to establish critical values at which nutrients in soil are optimised and available for uptake. Since then, there has been a body of research on phosphorus in soil describing how it interacts with other soil properties and how soil types affect P availability and soil test results. This paper describes these interactions, and questions whether our current test is capturing enough soil type information to allow us to improve our nutrient advice.

What do we measure in a soil P test?

Phosphorus in soil can exist in various forms, and some of this is immediately plant available and the remaining parts make up the reserves of P that are slowly available to crops and over time. When fertilizer P is added to soil some of this can go straight to the crop and some is assimilated into the soil and can be stored in reserve until the crop demands it. Soil P availability is optimised when P reserves have been built up to an optimum value where the soil can meet crop demands. The test we use for P in soil tries to recreate the acidic environment around plant roots and simulate supply of P from soil to plant. Our research has shown that soil properties can affect the soils ability to supply available P. These properties include organic matter (OM), soil pH, amounts of clay, and clay minerals such as aluminium (Al) and calcium (Ca). Clay minerals such as Al along with soil pH can affect availability of P in soil. Soils with excessive amounts of Al can cause P lock up or P fixing to occur and P becomes available when a threshold ratio of Al to P is reached (Figure 1). If soil pH is low (below 6.2) the availability of P is reduced, and testing for P will need to be repeated when soil pH has been corrected first. Conversely, a calcareous soils of high pH (>7) can interfere with Morgan's reagent, and the result will overestimate available P. In peaty mineral soils where OM is > 20 %, OM can prevent P from being absorbed into soil to provide reserves, in addition, high amounts of OM interferes with the efficiency of the test.

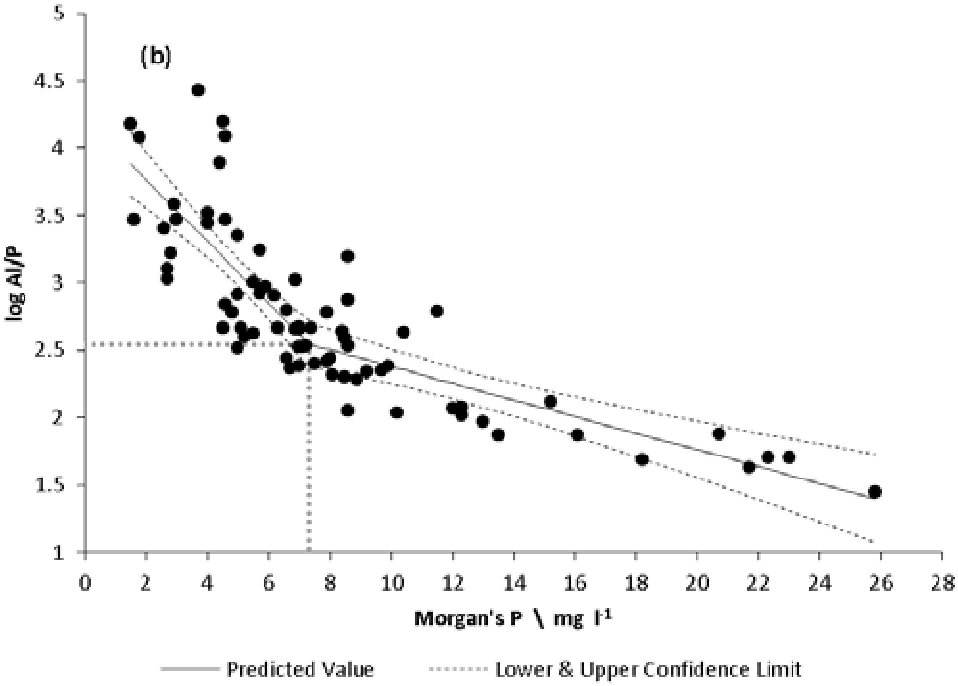

Figure 1. Soils above the change-point have high Al, and less available P.

Where is soil testing going?

Whilst most agricultural soils in Ireland have moderate amounts of Ca, Al and OM, and are generally neutral in pH, some soils namely peaty mineral, peats, acid brown earths and some gleys have those properties that can influence P availability and have interactive effects on the P test. Identifying which fields on the farm have these properties requires more than one analysis which can make testing time-consuming and more costly. Internationally, soil testing laboratories are looking toward including more soil properties in standard tests, in addition to developing methods that avoid chemical extraction. At Teagasc, Johnstown Castle we have established a new soil and crop sensing laboratory that is developing methods for scanning soils that give information on soil texture, OM, Al, Fe, Ca, lime requirement, in a single scan, with potential for portable analysis that can provide farmers with on-the-go testing for whole-farm soil analysis.

Figure 2. Portable soil spectrometers (left) for measuring multiple soil properties in one scan as an alternative to wet chemical tests (right) that are often sensitive to soil properties.

Efficient use of poultry manure for cereal production

Martin Bourke[1], Mark Plunkett[2] & Patrick Forrestal[2]

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Summary

- Fertilizer programmes including poultry manure can achieve the same yields as chemical fertilizer programmes if the nutrient content of the manure is known
- Poultry manure treatments showed no significant difference in grain protein compared with chemical N
- Ploughing down poultry manure gave the same grain yield as surface tilled in poultry manure in these trials
- Top-dressing with CAN or urea at tillering in a programme with poultry manure in the seedbed gave the same yields as a chemical N programme
- Significant cost savings with poultry manure, analysis is essential for efficient use

Introduction

Over the past number of years poultry manure has been used as an effective source of N, P and K for tillage crops. Results to date have been very positive especially for spring barley crops. Grower experience of this type of poultry manure had raised many questions as to the most effective time of application, and N fertilizer replacement value (NFRV). Poultry manure and organic manures generally bring a suite of nutrients when applied to land (Table 1.) One aim of these trials was to identify how the N value of poultry manure could be integrated into spring barley production without compromising yield potential and ability to achieve comparable grain protein to a chemical fertilizer programme. The poultry manure used in the trials was from a modern purpose built hen/layer house with ancillary facilities in place for drying the manure. As well as being dry it has low odour levels compared to wetter manures in the past.

What nutrients does poultry manure contain?

Poultry manure is a well balanced fertilizer of both major and minor nutrients.

Table 1. Total Nutrient Content of Poultry Manure by Analysis

Nutrient	N	P	K	S	Mg	Ca	Mn*	Zn*	Cu*	DM%
	kg/t				g/t					
2015	35□	6.8	17.5	4.5	1.2	39.2	317	225	22	89
2016	34□	9.9	20.0	--	5.4	34	363	344	18.7	87

□*According to the SI the N in poultry manures is deemed to be 50% available. Therefore ~17kgN/t or tonne is available for crop uptake during the growing season.*

2015 trial: Examined the following treatments at 150 kg available N/ha. All treatments had adequate levels of P, K and S applied independently. Treatments:

- Zero N control
- 150 kg N/ha as ammonium sulphate nitrate (ASN)
- Poultry manure (PM) supplying 85 kg available N/ha applied to stubble ground, ploughed in rapidly and top-dressed with 65 kg N/ha as ASN in early-tillering
- Poultry manure (PM) 85 kg available N/ha applied to furrow pressed ground and tilled in (during sowing) and top-dressed with 65 kg N/ha as ASN in early-tillering

Results of the trial in 2015 showed no significant difference (*P>0.5*) in grain yield or protein between treatments. The exception was the control treatment which had significantly lower grain yield (Figure 1).

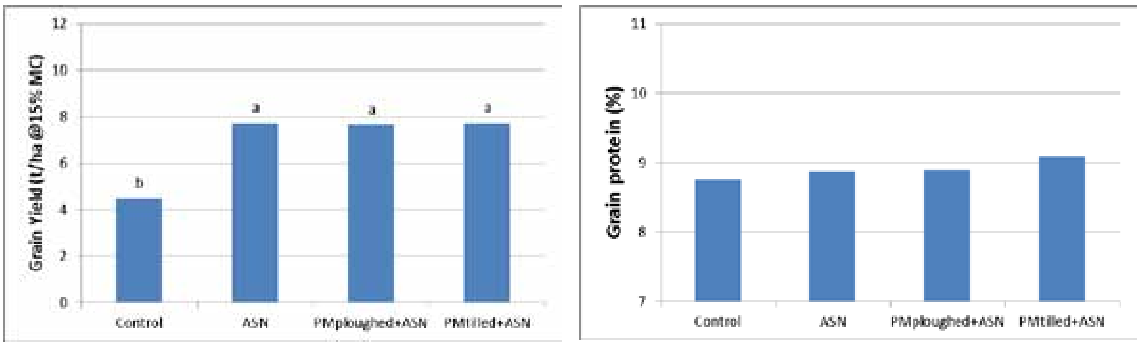

Figure 1. Grain yield and protein in response to a chemical N only compared to a manure and chemical N fertilizer programme. All treatments except the control have 150 kg available N applied.

2016 trial: Examined two sources of chemical N (CAN or Urea) in addition to poultry manure as a source of N with the objective of assessing a lower cost N programme. Adequate levels of P, K and S applied independently. Treatments:

- Zero N control
- 150 kg N/ha as calcium ammonium nitrate (CAN)
- Poultry manure (PM) 65kg available N/ha applied to stubble ground and ploughed in rapidly, followed by 50kg N/ha surface tilled in and top-dressed with 32 kg N/ha at early-tillering as a) CAN or b) urea
- Poultry manure (PM) 65kg available N/ha applied to ploughed furrow pressed ground, tilled in rapidly, followed by 50kgN/ha surface tilled in and top-dressed with 32 kg N/ha at early-tillering as a) CAN or b) urea

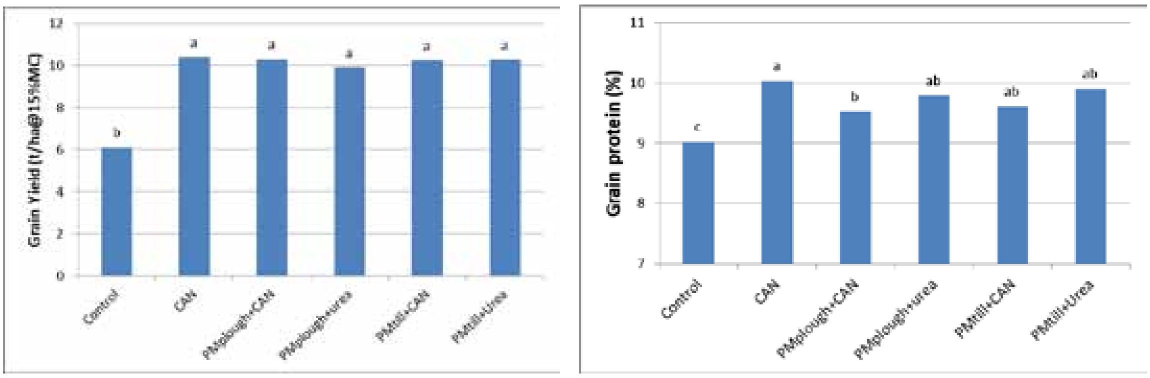

Figure 2. Grain yield and protein in response to a chemical N only compared to a manure plus chemical N fertilizer programme. All treatments except the control have 150 kg available N applied.

Results from the 2016 trial demonstrated that an N fertilizer programme using poultry manure with CAN or urea can give the same yield and comparable protein levels as a chemical N programme (Figure 2). Knowing the nutrient content of the manure is of key importance.

Cost savings using Poultry Manure

Using poultry manure to replace chemical fertilizer in a well balanced fertilizer programme can lead to significant savings on tillage farms (See example in table 2).

Table 2. Example fertilizer programme costs

Fertilizer Programme	N (kg/ha)	P (kg/ha)	K (kg/ha)	Cost (€/ha)
4.27 t/ha PM (68kg N) + 82 kg N/ha (Urea)	150	42	85	163
420 kg 10-10-20/ha + 108 kg N/ha (CAN)	150	42	84	225

Note: Assumed costs Urea €320/t, CAN €195/ton, 10-10-20 €350/ton and poultry manure €25/ton (including spreading charge)

Improving soil fertility health – An Advisors Experience

John Pettit[1], David P.Wall[2] & Mark Plunkett[2]

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Summary

- On intensive tillage farms sample soils regularly to monitor soil pH, P & K changes
- Nutrient management planning is an essential tool for managing soil fertility
- Compare soil test results and crop nutrient balances annually when formulating P & K advice for the coming season
- Change from traditional P & K fertilizers to more suitable P & K compounds which better meet the nutrient demands of high yielding crops within the rotation

Introduction

Soil fertility on many tillage farms in Co. Wexford is an issue of some concern with only 11% soil samples with optimal levels for pH 6.5, Index 3 for P & K. Addressing this issue of soil fertility on tillage farms in Co. Wexford has shown success in recent years. One such farm, to improve soil fertility, is that belonging to George and Kenneth Williamson, from Duncormick, Co Wexford, who participated in the Tillage BETTER Farm Programme. All fields on the farm were soil sampled annually to monitor soil pH, P and K. This high frequency soil sampling highlighted how quickly pH can drop in an intensive cereal rotation (Figure 1, soil pH decline of 0.22 pH units per year).

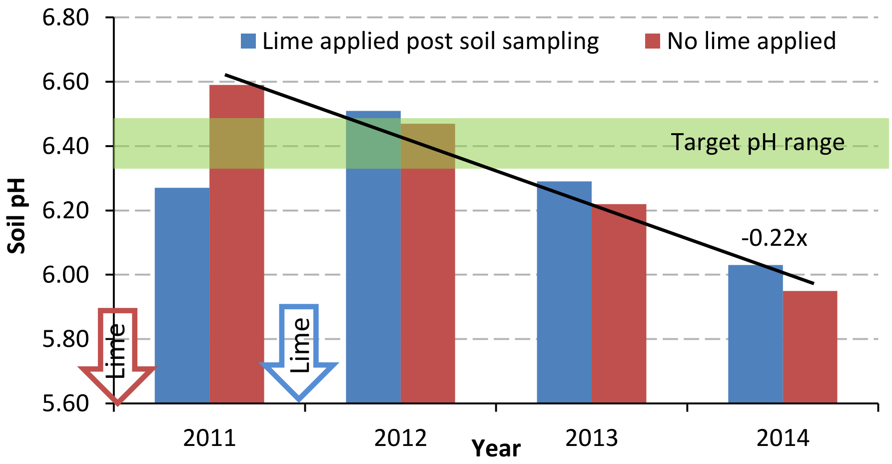

Figure 1. Change in soil pH over time & effect of lime application

Annual soil sampling highlighted the importance of testing soils more frequently to ensure that decisions are based upon more real time data. Findings on the Williamson's farm would suggest that sampling interval should be reduced to every three years.

Farm Planning

The planning process for a given cropping year with the Williamson's started the previous September. Factors effecting decisions include rotational slot for individual crops, soil type, soil fertility levels and the degree of exposure to an individual crop, amongst other factors. A detailed nutrient management plan outlining soil sampling results, lime requirements, major and minor nutrient requirements and application timings was completed for each individual field on the farm.

Tailoring Fertilizer Programmes

Field fertilizer recommendation are governed by a number of factors including current soil P & K levels, potential crop P & K offtake and the nutrient balance in the previous year. On one field an average of 40 kg/ha P and 88 kg/ha K were removed over a four year period. With high yielding winter cereal crops P & K offtakes can be very significant, hence when giving a fertilizer recommendation it is important to consider the previous year's nutrient balance to ensure you achieve your objective of either maintaining or building soil nutrient levels within an individual field.

Crop Rotation P and K planning

Traditionally the Williamson's produced spring barley rotated with sugar beet. Sugar beet resulted in surplus P & K to crop removal, and was available to supplement the following crops nutritional requirements over the life of the crop rotation. The loss of the sugar industry in 2006 and the subsequent use of traditional fertilizer compounds resulted in a decline in soil P & K levels up to 2009. Since then average soil P level (3.93 mg/l in 2009) has increased to 5.18 mg/l in 2014. This was achieved by using high P & K fertilizer compounds such as 10-10-20 and in more recent years 11-9-22.

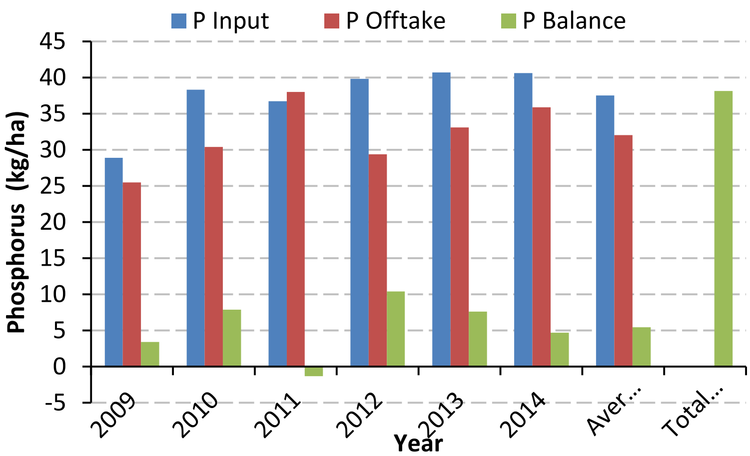

Figure 2. Annual farm phosphorus input, offtake, balance and total cumulative P surplus (kg/ha) over the 2009 to 2014 period.

An increase in the quantity of fertilizer P applied since 2009 has resulted in a P surplus of total 38 kg/ha between 2009 and 2014 across the farm (Figure 2). This surplus P resulted in an increase in soil P of 1.25mg/l (i.e. 30 kg/ha P surplus to increase soil test P by 1 mg/l). This highlights the time taken and quantities of P input required to build-up soil P levels. It also demonstrates the importance of, at least, matching fertilizer P inputs to the levels removed by the crop in order to maintain or build-up soil P levels over time.

The average soil K level in 2009 was 100.7 mg/l, and this has also increased to 127.6 mg/l in 2014. This increase in soil K levels has resulted from surplus K applications of 21.7 kg/ha in recent years (i.e. 0.81 kg/ha of surplus K to increase soil K by 1 mg/l). This highlighted how quickly soil K can respond to fertilizer management, and the need for frequent soil testing and calculating nutrient balances annually to ensure that the objectives of either maintaining or building soil nutrient levels within an individual field are achieved.

Spreading fertilizer precisely: new products and challenges

Dermot Forristal

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Summary

- Urea is likely to be used much more on tillage farms which will present challenges for spreading at wider bouts because of its lower density
- There is considerable variation in particle size distribution and particle strength with urea; select those with good physical characteristics
- Fertilizer spreaders will differ in their ability to spread urea. Look for spread patterns and low coefficient of variation (COV) spread results; preferably from independent sources. Choose bout width carefully
- There can be a serious deterioration in spread pattern and application evenness between the test hall and the field, particularly with wind-sensitive urea
- Choose spreaders and fertilizers that are supported by test-based resources that indicate the quality of spread and allow the spreader to be set correctly

Introduction

Precision farming in a fertilizer context often implies variable rate application based on soil analysis or crop reflectance. While these systems are currently limited there is a much more immediate precision issue that needs attention. Fertilizer must be applied evenly across the chosen bout width. This precision is frequently not achieved and the likely increase in use of urea on tillage farms will create spreading challenges, due to the physical characteristics of the product, particularly its density. Growers need to carefully consider the suitability of the fertilizer and spreader for the task, and to set the spreader for the task.

Fertilizer quality and spreading

Modern fertilizer spreaders are all broadcaster type which may have to accurately throw fertilizer particles up to 30m to achieve an even overlapped spread pattern at wider bout widths. Uneven spreading can easily cause yield losses worth €22 to €55/ha before lodging or crop quality is considered. The factors which influence even spreading at a specific bout width are:

- Spreader design; particularly the disc, vanes and fertilizer delivery point
- Appropriate setting of the spreader based on fertilizer type and bout width
- Fertilizer physical characteristics (density, granule size/shape, strength)
- Field conditions, specifically wind

A fertilizer particle must have a certain mass to allow it capture enough energy to be thrown a distance. Dense relatively large particles are more easily thrown as they can capture the energy and are less likely to be slowed by wind resistance.

Fertilizer physical characteristics are defined by particle size distribution; density and particle strength (Table 1). Urea, like all fertilizer types, is variable. In the past small low-density prills were unsuitable for wider bout widths, but products with much larger particle size distributions have made wider spreading possible. However, the density of urea at 0.7 - 0.83 kg/litre, makes it more difficult to spread and more susceptible to wind. Also some urea products have poor particle strength and subject to breakage at high disc speeds.

Table 1. Physical characteristics of different fertilizers

Product	Particle size distribution (% in category)				Density	Strength
	<2mm	2-3.3mm	3.3–4.75mm	>4.75mm	Kg/litre	Kg
CAN	0	6	84	10	1.03	9.3
NPK	0	35	45	20	0.93	9.8
Urea 1	95	5	0	0	0.77	0.39
Urea 2	5	80	15	0	0.74	1.1
Urea 3	1	56	42	1	0.77	6.1

Ensuring an even spread

Urea spread patterns and evenness statistics (COV) at the desired bout width should be considered before purchasing a spreader. Independently tested data should be valued more than manufacturer's own data. A wide evenly-shaped spread pattern (Figure 1) will produce even spreading in the field, whereas an irregular shouldered shape (Figure 2) is challenging to get right in the field. Fertilizer with larger particle sizes, good density and high particle strength should be sought. The spreader should be correctly adjusted for the fertilizer and bout width being used. Many manufacturers have made this much more accessible using internet tools and phone apps. Where possible, in-field tray tests should be used to check the spread pattern.

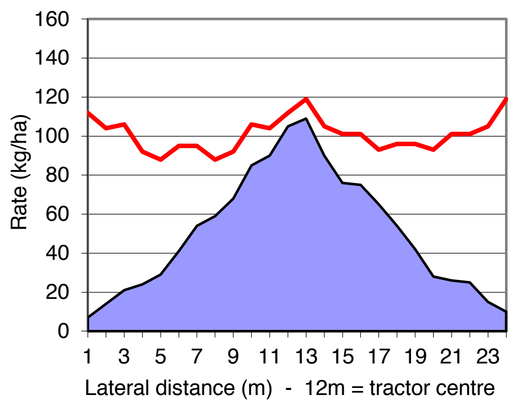

Figure 1. Good spread pattern

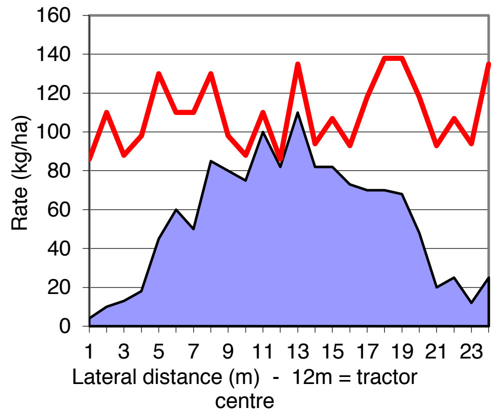

Figure 2. Poor spread pattern

Urea, because of its density, will often produce a poorer spread pattern than other fertilizers, effectively limiting bout width and demanding more careful setting. Wind will have a greater impact on its performance. Carefully consider the bout width that can be achieved when selecting fertilizer and machines. Blends of urea and high density products present a particular challenge as the components of the blend could spread differently. For example urea may be concentrated near the tractor and P and K between the tramlines. This may not be evident on a tray test as both products would need to be tested independently with the spreader set for the blend. Finally, future spreader technology involving particle trajectory monitoring and real-time control of spreader setting will help optimise spreading in the field.

Conclusion

Using urea at wider bout widths is a challenge requiring careful selection of fertilizer & spreader; selection of urea with good physical characteristics and appropriate setting of the fertilizer spreader. In addition evenness of urea application is more easily impacted by wind. The relative scarcity of independent testing of spreaders with different fertilizers is a constraint when selecting machines.

Major and micro nutrient advice "Green Book"– New Developments

David P Wall & Mark Plunkett

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Summary

- A full review and update of the Teagasc "Green Book" Major and micro nutrient advice for productive agricultural crops was under taken in 2016.
- Review objectives
  - to provide sufficient information to allow agricultural and farm advisors and consultants to recommend optimum levels of major and micro nutrients for the most important agricultural and field horticultural crops
  - to update nutrient recommendations for grassland and crop production systems based on the latest scientific evidence
  - to provide guidance in terms the maximum allowable N and P limits under current Nitrates Directive-NAP rules (SI 31 of 2014)
  - to facilitate better nutrient management planning on Irish farms into the future
- The 4th Edition of the Green Book will be available to guide fertilizer advice for the coming season

Introduction

A major responsibility of the research staff at Johnstown Castle has been the publication of leaflets, booklets and manuals giving nutrient and trace element advice for grassland and crops. This began in the 1940s and was the scientific basis for soil analysis (Coulter, 2000) and the most recent manuals were published by Coulter in 2004 and Coulter and Lalor 2008. This version has now been enhanced and expanded to produce the present volume (4th Edition, Wall & Plunkett, 2016).

A major objective in this revision was to ensure that it was comprehensive and that it contained sufficient information to allow agricultural and farm advisors and consultants to recommend optimum levels of major and micro nutrients for the most important agricultural and field horticultural crops. The manual sets out to minimise conflicts between the need to ensure an economic return from grassland and tillage farming on the one hand, and concerns about losses of nutrients to water or gaseous emissions to the atmosphere on the other.

Many of the changes in this 4th edition were made necessary by legally binding requirements of the statutory instrument SI 31 of 2014 – the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006. This SI has major implication for use of N and P in farming, both for the farmer and for organisations and advisers recommending levels of nutrient use for agriculture. It has been the intention of Teagasc that fertilizer advice, if followed carefully, should have the desirable effect of optimising yield, protecting the environment, as well as saving money for the farmer. In revising this document, this policy has been continued, within the constraints of SI 31 of 2014, particularly when dealing with the environmental consequences of N and P use.

Fertilizer rates for optimum yield may sometimes exceed the maximum allowed by SI 31 of 2014. For example, N fertilizer rates for high yielding crops require that proof of historic yields is available, although, historic yields are not necessarily a good predictor of expected yields. Nutrient advice tends to be self-correcting when accompanied by frequent soil testing. Thus, if soil variation or sampling errors cause nutrient applications to be higher than necessary, this will tend to be corrected following the next soil test. Since soil nutrient levels change slowly under most cropping systems, it is usually safe to base fertilizer advice on soil tests for four to five years from the date of sampling. Where soil analysis suggests that no nutrient applications are needed, or with very light soils which have limited buffering capacity, it is prudent to have soil analysis carried out every three years.

Teagasc Green Book, 4th Edition Summary of Changes

New Sections

- Soil Types and Nutrient Cycling: Information on the major soil types in Ireland and their influence on nutrient cycling and management, including links to further information of Irish soils
- Fertilizer Ingredients: Definitions and information on the main fertilizer ingredients available in Ireland
- Adaptive Nutrient Management Planning; NMP–online: Information on the new nutrient management system "NMP-online" and how it can be used to facilitate better nutrient management planning and sustainable outcomes for farmers into the future
- Nutrients for Energy Crops: New information and nutrient recommendations for energy crop production

Revised Sections

- Soil Acidity and Liming: Improved information on importance of soil pH correction and new information on lime and lime products has been included
- Nutrients in Organic Manures: Updated the fertilizer replacement values for slurries and provide new information nutrient constituents in a range of organic manure and biosolid types. Information on tools to measure slurry variability and how to maximise slurry efficiency
- Grassland: New N advice for beef and sheep systems and suggested application timings for fertilizers
- Cereals: New advice on N application timings for cereal crops
- Potatoes: New N advice for potatoes, which considers production system and haulm longevity
- Oilseed Rape: New advice on N timing based on density of the crop and leaf area index
- Vegetable Crops: Updated of N, P and K advice for vegetable crops based on best available information has been included

Teagasc fertilizer advice is not static but is reviewed constantly in the light of new national and international research findings, changes in farm practices, nutrient regulations and the onset of new grass and crop varieties with different nutrient requirements.

Acknowledgements

We would like to thank all who helped organise the Soil Fertility Conference 2016. We would especially like to thank, Mary Foley, Connie Conway, Eleanor Butler, Sharon Brennan Francis Carroll, Therese Dempsey and Eric Donald.

We would like to thank our chair persons Andy Doyle and Jack Nolan. We also thank the speakers and contributors to the conference proceedings.

Finally, we would like to acknowledge all who contributed to this review process and to delivery of the new Teagasc "Green Book"

Notes

Notes

5 STEPS TO BETTER SOIL FERTILITY

1 SOIL TESTING

- Provides you with vital information about your soils
- A foundation for your fertilizer plan
- A small farm expense costing in the region of €1.25/ha/yr and is valid for 5 years
- A standard soil test will give the soils fertility status as follows; pH, lime requirement, phosphorus (P) and potassium (K).

2 SOIL PH & LIME

- Lime improves the availability of Nitrogen, Phosphorus, Potassium, Sulphur, Calcium and Magnesium
- Lime at least every 5 years
- Ground limestone can be spread at any time
- Apply lime as per soil test report. Avoid over-liming as it can result in trace element imbalances.

3 TARGET INDEX 3 FOR P & K

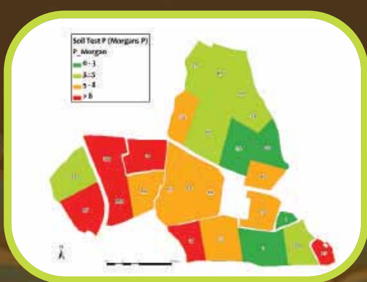
- Index 3 is the optimum level for crop growth
- Only by soil testing will you know your P & K levels
- Index 4 soils (high fertility) are a resource - use them to save money on fertilizer
- Index 1 and 2 soils (low fertility) need additional nutrients
- Monitor your soil fertility by looking at previous analysis.

4 SLURRY & MANURES

- Plan when and where slurry/manure will be best utilised
- Aim to apply slurry in spring during moist cool conditions
- Apply slurry and manures on land that requires P & K
- Take account of nutrients contained in slurry if applying chemical fertilizer to the same area
- Always observe buffer zones from watercourses and wells.

5 NUTRIENT BALANCE

- Develop a fertilizer plan for your farm
- Get the best value from fertilisers and organic manure
- Enhance crop yield and animal performance
- Reduce environmental risks due to field losses of excess nutrients
- Potential cost savings when all nutrient inputs are accounted for.



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