THE FERTILIZER ASSOCIATION OF IRELAND

Proceedings of Spring Scientific Meeting 2015

"Profiting from Soil Fertility"

3rd February 2015

Horse and Jockey, Thurles, Co Tipperary

www.fertilizer-assoc.ie

Publication No. 50

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Contents

Lime and phosphorus for maximum productivity

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Introduction

Phosphorus (P) is an essential element for both plant and animal life and plays a key role in all living cells (Johnston *et al.,* 2014). To meet the needs of their crops, farmers apply P either as inorganic (P fertilizer) or organic (animal manures and slurries) to support optimum plant growth and ensure soils do not become deficient in P (Culleton *et al.*, 2002). This then ensures that crop growth is not restricted by P and that grass contains sufficient P for dietary needs of the grazing animal.

Agricultural productivity and ultimately the profitably of Ireland's ruminant production systems (dairy, beef, sheep) are reliant on grass as the main component of the diet in ruminant livestock systems (O'Donovan *et al.,* 2011). Increased grassland productivity requires increased nutrient input and thus efficient use of both inorganic and organic fertilizers will help ensure financial reward for the farmer.

Phosphorus fertility has been declining in Irish soils in recent years according to results of soil tests analysed through Teagasc (Plunkett, 2012) and may be traced back to declining amounts of P fertilizer used over the course of the last decade. This creates challenges for the production targets within Food Harvest 2020 and the post-quota production era. This concern and increased anecdotal reports of animal showing symptoms of P deficiency lead to a research project being established to investigate these issues. Nutrient use efficiency is and always has been a fundamental element of the Crops, Environment and Land Use Research programme at Johnstown Castle and a key objective of this paper is build on previous work and provide up to date research that can be utilised by today's farmers.

Soil pH and Lime

Soil pH is a critical factor in ensuring that as much as possible of the total P in soil is available for uptake by grass and crops. Soils contain a relatively large quantity of total P. However, only a very small proportion of this P is available for uptake by plants at any stage. The majority of the P (usually greater than 99%) remains in the soil in unavailable forms. The standard soil test (Morgan's soil test in Ireland) is designed to estimate the ability of the soil to release P to plants in forms that are available for uptake.

The amount of P in the soil that becomes plant available is strongly influenced by the soil pH. The optimum soil pH for mineral soils is pH 6.3 to 6.5. If the pH is either too low, or too high, the availability of soil P is reduced, and less of the total P that is in the soil will be released to plants for uptake.

Most Irish soils suffer from soil pH being too low (i.e. acid soils) rather than too high. Approximately 60% of grassland soil samples analysed through Teagasc have a soil pH <6.0. Soil pH can be increased by applying lime. Soil pH and lime requirement are standard tests that are included on a soil test report.

Lime increases P availability

It is generally understood that different Irish soils will react differently to P and lime additions. Attempts have been made to understand this variability in ways that can improve soil-specific advice on farms. However results to date have failed to explain this response fully. In order to try and improve our understanding of P and lime in Irish soils, a study was set up at Johnstown Castle to demonstrate P and lime application on soil nutrient availability. A range of contrasting soils types from around Ireland (16 in total) were collected and treated with either fertiliser P, lime, or both, and incubated in controlled conditions. After 3 and 12 months, the soil test P was measured in each soil and compared to the soil test P level at the start. Results showed that on average across the 16 soils, there was an increase in the soil test P with both the lime and P fertiliser. The highest increase in soil test P was found when P and lime were both applied to the soil (Figure 1).

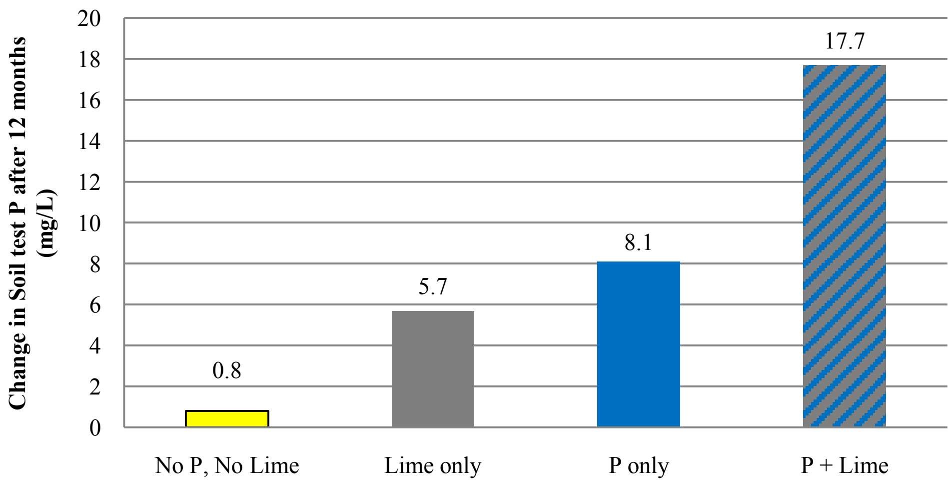

Figure 1. Average change in soil test P (Morgan's) across 16 soils treated with P (100 kg/ha of P), Lime (5 t/ha of lime), and P + Lime and incubated over 12 months in controlled conditions.

However the average results in Figure 1 hide the large variation that becomes apparent when all soils are compared together (as shown in Figure 2). These results show that across the 16 soils, only between 4 and 31% of the fertiliser P applied was recovered in soil test after 12 months, highlighting the high capacity of soils to bind P in unavailable forms.

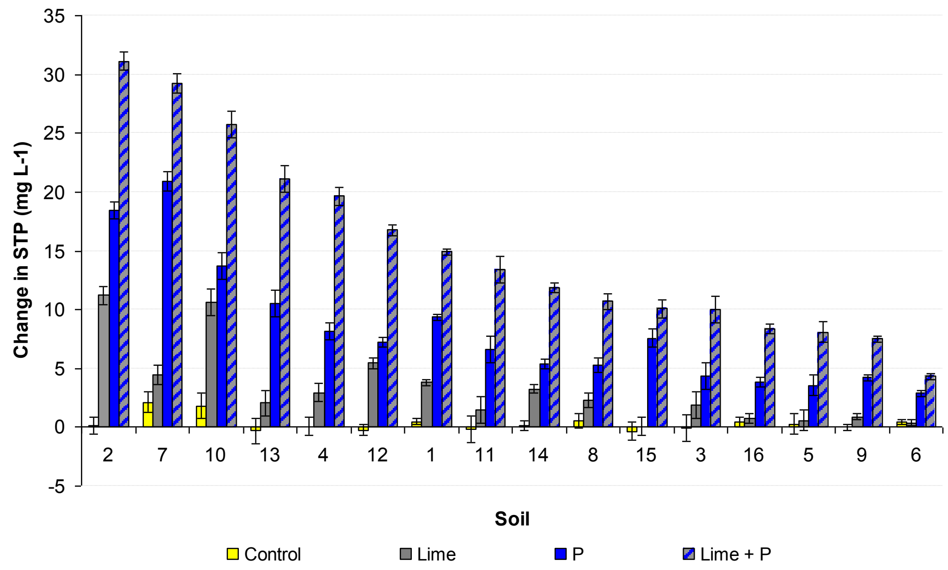

Figure 2. Variation in the change in soil test P (STP) in response to lime and P application to 16 soils over a 12 month incubation period.

These results indicate two things. Firstly, a large proportion of fertiliser P applied can be fixed by the soil and made unavailable after application. Secondly, lime has a key role to play to reduce this fixation of P and increase its availability for uptake and utilisation by grass and crops.

This experiment also examined the effect of time (3 months and 12 months) on the soil P concentration and soil pH. In general, the effectiveness of lime on increasing P availability increased over time. However this was not the case in all soils and shows that the lime (once thoroughly mixed in soil) has a relatively quick impact on the soil pH. The effect of time had little or no effect on the soil P concentration.

This experiment also examined soil Al which has been shown by Daly *et al.* (2001) and Murphy *et al.* (2009) to be particularly important in control of soil P availability, as it has a high capacity to bind P and make it unavailable. The soil pH impacts on the prevalence in the soil of Al in forms that will fix P, with fixation being more prevalent at lower soil pH levels. The effect of P and lime on soil Al availability is shown in Figure 3. Lime significantly reduced the solubility of Al in the soil compared to the increase in soil Al where P was applied on its own. This may be an important factor as to why lime increases the P availability as seen in Figures 1 and 2. This point may be of particular importance in the evaluation of non-traditional liming products to reduce soluble Al to a greater or lesser extent than traditional ground limestone.

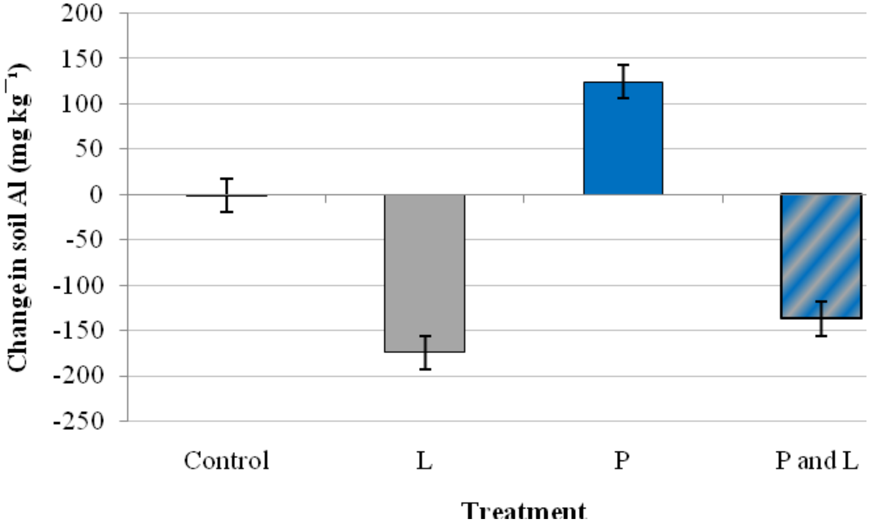

Figure 3. Effect of P and lime (L) on the mean change in soil Al

Irish farmers are being encouraged to increase output across all food producing sectors. Soil fertility and especially P will be important factor to ensure the success of this drive to increase production. Ensuring efficient use of nutrients will be required in order to support grass and crop production in the future. This work clearly demonstrates that it is critical to first get soil pH correct through a planned and organised liming programme on the farm.

Fertiliser P increases grass production

The effect of P fertiliser on grass dry matter yield and the herbage P concentration has also been investigated in two separate field studies at Johnstown Castle. The first study examined the effects of long term programme of P fertilizer application to grassland. This trial measured grass dry matter yields and the herbage P concentration at 4 rates of P fertiliser (0, 15, 30 & 45 kg/ha of P) on two low P fertility (Index 2) sites since 1995. On average, grass dry matter yield (t/ha) over the 17 years of the trial was increased by 11% by the application of fertiliser P compared to plots that received no P during the experiment (Figure 4). The increase in herbage yield was greatest during the spring period.

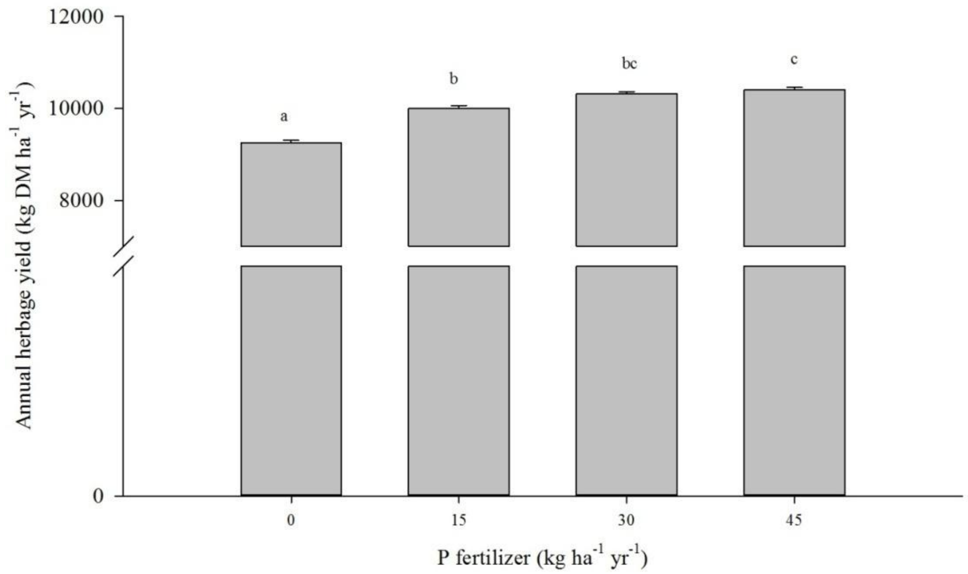

Figure 4. Effect of P fertilizer on the mean herbage yield over 15 years of the trial.

This experiment also showed that the rate of P fertiliser applied (0 to 45 kg/ha) had a large effect on herbage P concentration in spring and summer. Having a P concentration in herbage of 3.5 g/kg is required throughout the grazing season to meet the dietary requirements of productive animals. This experiment showed that during the maximum grass production period (May/June) and during summer months (July), grass herbage concentration was not maintained above 3.5 g/kg P, even with the highest P fertiliser application of 45 kg/ha (Figure 5, site 1 and figure 6, site 2). On a national scale, survey data collected by Kavanagh *et al.* (2014) found a similar trend of lower herbage P concentrations during mid-season.

In this experiment, all the fertiliser P was applied in early spring (February). These results indicate that splitting P application with a "little and often" approach during the spring and summer may help to ensure that there is sufficient P in grazed grass to meet animal requirements. To examine this further a separate experiment in Johnstown Castle has shown that splitting P fertiliser into a number of applications between April and July gave higher herbage P concentrations in July than where the P fertiliser was all applied in a single application in spring, without impacting negatively on grass yield.

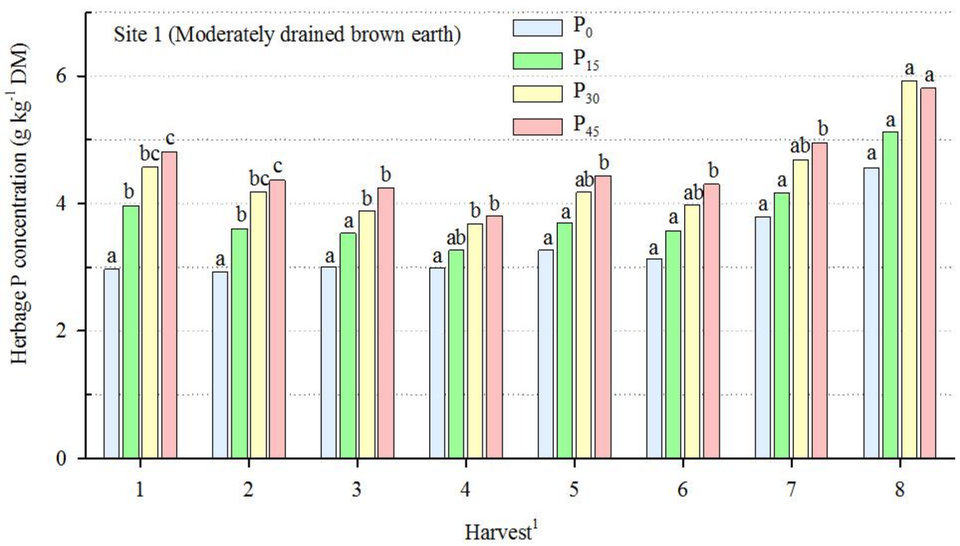

Figure 5. Effect of P fertilizer rate on herbage P concentration at each harvest (site 1)

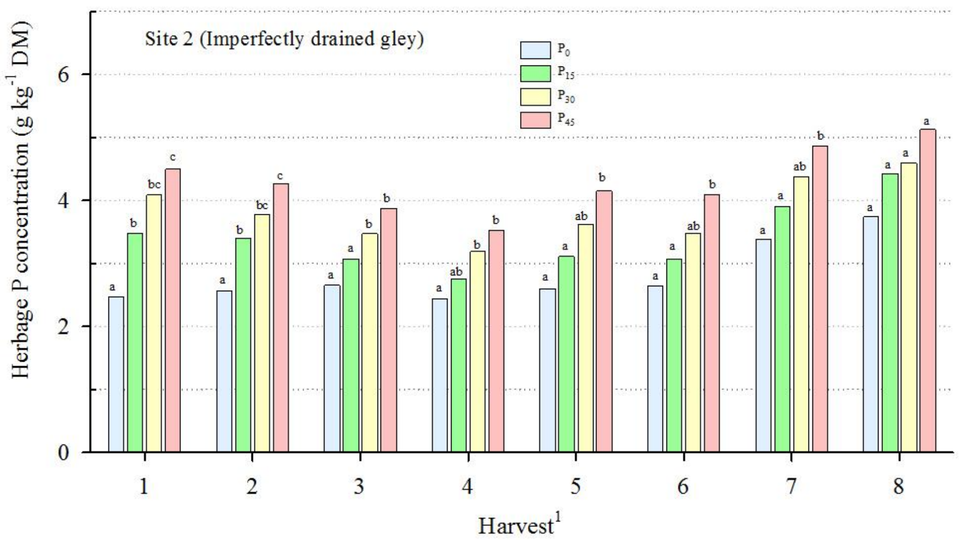

Figure 6. Effect of P fertilizer on the herbage P concentration at each harvest (site 2).

A second field experiment was established to look at the interaction effects of N, P and lime on the herbage DM yield and herbage P concentration. This trial was set up on two sites with contrasting soil fertility status. Site 1 had a soil P concentration of 4.8 mg/L (Index 2) and a soil pH level of 5.4, while site 2 had a soil P concentration of 14.9 mg/L (Index 4) and a soil pH level of 6.2.

Over 12 harvests taken over a year and a half (July 2011 to October 2012), both sites showed a significant yield response to P fertilizer (Table 1).

Table 1. Significance of either N, P or lime applications (P values) on the herbage yield for each site and harvest. *(Harvest labels refer to year and harvest within that year. E.g. Harvest 2.3 relates to third harvest within year 2).*

	Site 1			Site 2		
Harvest	**N**	**P**	**Lime**	**N**	**P**	**Lime**
1.1	*<.0001*	*0.0004*	0.3966	*0.0082*	*0.0246*	0.0784
1.2	*<.0001*	0.7721	0.7115	*<.0001*	0.7608	0.3612
1.3	*<.0001*	0.1758	0.6265	*<.0001*	0.1008	0.5712
1.4	*<.0001*	0.1981	*0.0242*	*<.0001*	0.567	0.7082
2.1	*0.0135*	0.1256	0.726	*0.0049*	0.6002	*0.0073*
2.2	*<.0001*	*0.0267*	*0.0482*	*<.0001*	0.2007	0.1123
2.3	*<.0001*	0.8826	*0.0019*	*<.0001*	0.1446	0.2089
2.4	*<.0001*	0.0804	0.3059	*<.0001*	*0.0362*	0.113
2.5	*<.0001*	0.0704	0.0849	*<.0001*	0.0911	*0.0274*
2.6	*<.0001*	0.5746	0.1509	*<.0001*	0.4395	0.0774
2.7	*<.0001*	0.1885	0.1706	*<.0001*	0.117	0.2928
2.8	*<.0001*	0.7386	*0.0211*	*<.0001*	0.1016	0.1408

Phosphorus is known to be an important nutrient for early plant development (Grant, 2001) and in this study both sites produced a significant yield increase at reseeding time. The application of P fertilizer early in the year is also seen as important for grass growth early in the growing season, and this was also confirmed with a significant response to P fertilizer on the low P site after P fertilizer application in early spring. The high P site also showed a response to P fertilizer during the mid-way point during the year. This response may be linked to the reduced herbage P concentration that is seen in the long term experiment (Herbage P concentration dilution due to a higher P requirement for rapid growth). The cumulative response to P fertilizer addition on herbage yield (total of 12 cuts) is shown in Figure 7. Both sites had a significant response to P addition of 20 kg/ha/yr. With the addition yield amounting to 1214 kg/ha of DM in the low P site and 1244 kg/ha of DM in the high P site.

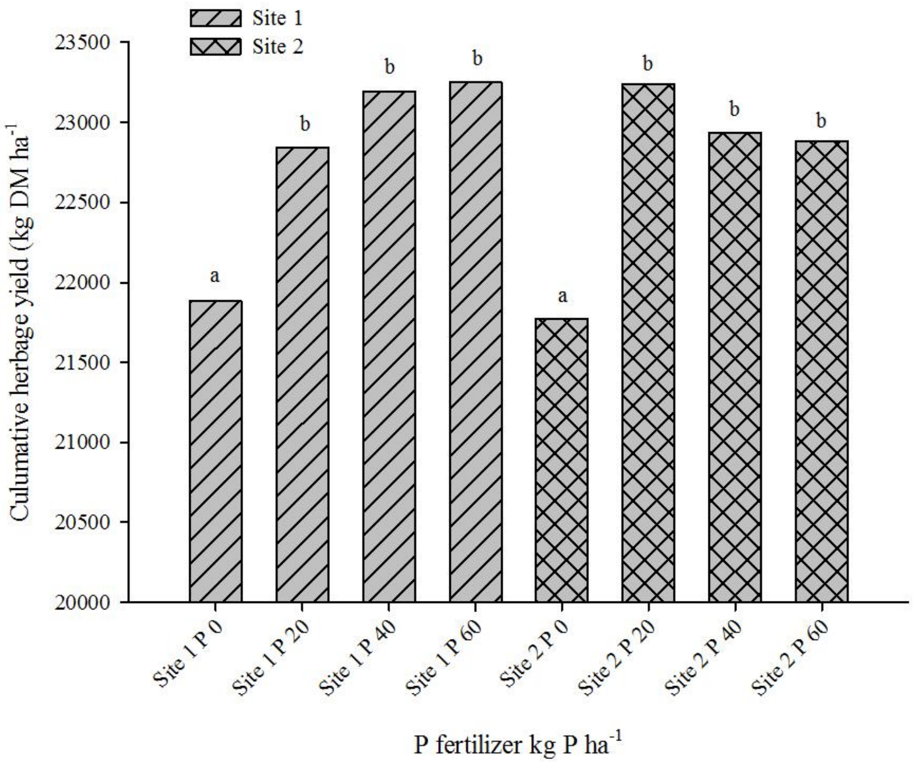

Figure 7. Effect of P fertilizer on cumulative herbage yield (kg/ha of DM) in both sites. Different letters denote significance difference within each site.

The interaction between N, P and lime was most apparent for the herbage P concentration in this study and is shown in Table 2. Increasing the nitrogen fertilizer level caused a reduction in the herbage P concentration. It is likely that this is caused by a dilution effect due the extra grass production following nitrogen application. Increasing the level of P fertilizer applied offset the reduction from the nitrogen application and maintained/increased the herbage P concentration. The lime and P interaction which was only significant in site 1 may also relate to the dilution effect and allude to the increase in herbage yield due to lime application which caused the herbage P concentration to be reduced.

Table 2. Mean herbage P concentration (in g/kg) for interaction (N*P and Lime*P) and main effects of N, P and lime across all harvests at each site. (Subscripts of "N" and "P" indicate annual rate of application (kg/ha). Subscripts of "L" indicates rate of application of Lime (t/ha) in Year 1).

	Site 1 *(P Index 2, pH = 5.4)*					**Site 2** *(P Index 4, pH = 6.2)*				
N*P										
	P_0	P_{20}	P_{40}	P_{60}	Sig.[1]	P_0	P_{20}	P_{40}	P_{60}	Sig.[1]
N_0	3.58	3.7	3.73	3.81	*	4.42	4.41	4.43	4.55	*
N_{150}	3.29	3.44	3.56	3.6	*	4.18	4.2	4.31	4.34	*
N_{300}	3.09	3.35	3.5	3.65	*	3.81	4.01	4.14	4.25	*
Lime*P										
	P_0	P_{20}	P_{40}	P_{60}		P_0	P_{20}	P_{40}	P_{60}	
L_0	3.37	3.59	3.73	3.83	*	4.16	4.25	4.35	4.42	NS
L_5	3.27	3.4	3.46	3.54	*	4.12	4.17	4.24	4.34	NS
N										
	N_0	N_{150}	N_{300}			N_0	N_{150}	N_{300}		
	3.7	3.47	3.4		***	4.45	4.26	4.05		***
P										
	P_0	P_{20}	P_{40}	P_{60}		P_0	P_{20}	P_{40}	P_{60}	
	3.32	3.5	3.6	3.69	***	4.14	4.21	4.3	4.38	**
Lime										
	L_0	L_5				L_0	L_5			
	3.63	3.42			***	4.3	4.21			*

[1] *Significant differences are denoted as follows:*
*NS - P value>0.05; * - P value< 0.05; ** - P value< 0.01; *** - P value< 0.001*

Implications for farm advice arising from this work

- Farmers should sample and test soils to know soil pH and nutrient status.
- Correcting soil pH by applying lime where required is critical to maximising the availability of P in soil and fertilisers - maintain soil pH between 6.3 and 6.5 by regular lime applications based on soil test results.
- Phosphorus fertiliser is important for grass DM yield particularly in spring and at reseeding time.
- Apply P in a "little and often" pattern during spring and summer to increase the nutritional value of grass in terms of P concentration.

Conclusion

Forgetting P as part of a balanced NPK fertilizer regime can lead to a reduction in both yield and quality (herbage P concentration) of grass. Phosphorus fertilizer is crucial for maximum yield with particular relevance placed on P at reseeding, even on Index 4 soils. Caution should be advised on low P soils that receive no P during the year and/or high levels of nitrogen, as sub-optimum herbage P could manifest particularly during periods of high growth. The results from this study highlight that soil pH is fundamental to increasing availability of soil P and that achieving optimum soil pH should be seen as the first step to increasing soil nutrient availability. It should be noted that all farmers are subject to nutrient use legislation which may limit P fertilizer application and even omit altogether in some cases. There is no restriction placed on lime use.

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Smart Farming: Reducing costs inside the farm gate through better resource management

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[2]IFA Environment Executive

Background

Improving farm incomes is at the centre of all of IFA's activities. This is the driving force behind the voluntary Smart Farming programme. This initiative focuses on ways to reduce costs inside the farm gate through better resource management in eight key areas: feed, grassland, water, inputs, time management, soil fertility, machinery management and energy use. The programme is led by IFA and brings together the knowledge of Teagasc, the Fertilizer Association of Ireland, EPA, UCD and others; communicating it in a targeted way to improve farm incomes. It delivers results: during 2014, over 600 farmers across the country participated and saw members of their discussion groups identify average cost savings of €6,600 per farm. Smart Farming is also enhancing the countryside. Measures adopted by participating farmers will result in: less risk of run-off to water courses; extended grazing of grass; better targeting of fertilizer application; reduced energy and inputs use; and reduced greenhouse gas emissions. This is sustainable intensification in action, achieving the double dividend of saving farmers money and maximising output, while protecting the environment. It also contributes to the smart green growth that underpins the vision of *Food Harvest 2020*.

Smart Farming: Reducing costs

Over the past decade, spending on inputs has increased by over 50% from €3.2b to €4.9b, representing over 70% of the farm gate value of output produced. During this same period product price and input cost volatility have also increased significantly. Therefore the focus on resource efficiency and the use better use of inputs through the Smart Farming programme makes good economic sense. Every 1% reduction in inputs use will lead to a saving of €49m to the sector.

IFA continues to lobby for policy changes that can result in cost reductions. The Association is seeking to address at EU level the issue of market concentration and the unbalanced power held in the hands of a small number of multinational input suppliers. A number of technology initiatives are being developed by IFA to enable farmers to obtain and contribute to timely price information. Increased price awareness empowers farmers to bargain for better prices by comparing costs and making informed decisions on managing their own cost base.

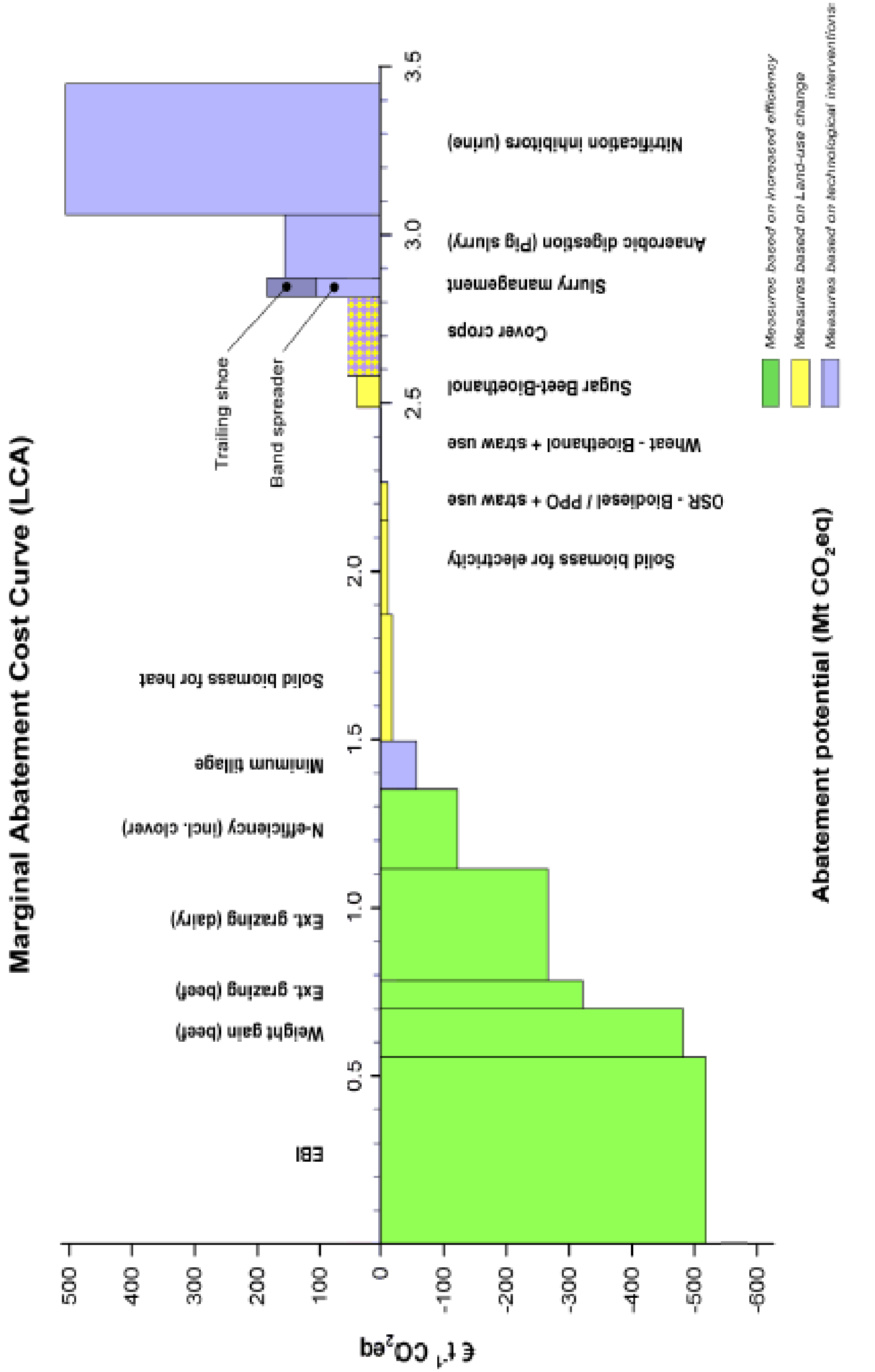

Figure 1: Marginal Abatement Cost Curve, based on LCA analysis (Source: Teagasc, 2012)

Smart Farming: Improving the environment

In 2012 Teagasc published a marginal abatement cost curve for Irish Agriculture (Figure 1) that qualified the opportunities for abatement of agricultural greenhouse gases, as well as the associated costs/benefits.

Over 80% (c.2.8 Mt CO_2 eq.) of the measures identified are considered to be cost-efficient. The adoption of these measures is good for the environment and also saves farmers money. The development of the Smart Farming programme was influenced by these findings. Focus areas and agencies that contributed to the programme are presented in Figures 2 and 3, with each participating agency generously providing their expertise and time.

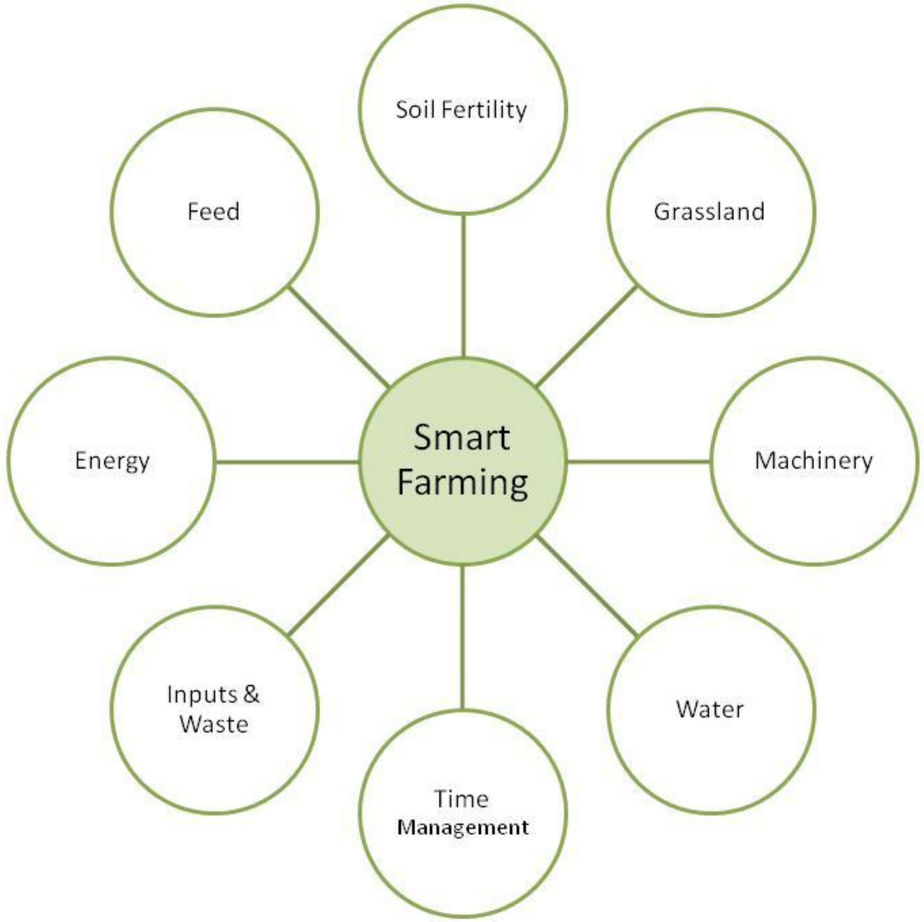

Figure 2. Smart Farming – Focus Areas.

Figure 3. Smart Farming – Participating Agencies.

Smart Farming: Delivering results on farms

The agencies identified in Figure 3 collaborated to produce a Smart Farming guide, which is a summary of top-tips to save money and reduce waste while safeguarding the environment. This guide is available through the farm directory www.ifarm.ie and www.smartfarming.ie. In 2013, six pilot cost saving studies across the main farming enterprises were completed using the information contained in the guide. Average cost savings of €5,000 were identified on each farm.

In 2014 a further 30 discussion groups took part in the Smart Farming programme, with average cost savings per participating farm of €6,600. Table 1 outlines some of the savings identified. It also illustrates the fact that capital investment is often required in order to deliver the savings.

The focus for 2015 will remain on identifying a minimum of €5,000 cost savings on the farms that participate in this voluntary initiative.

Table1. Examples of cost savings identified on host Smart Farming farms

Focus Area	Action	Economic Return	Environmental Dividend
Soil Fertility	Apply Lime 2.5 ton/ac – 60% of the farm Low soil pH Cost €4,500	Release equivalent of 2 bags of CAN/ acre Save 9 tonnes of CAN/ year = €2,610 Payback period = 2 years	More efficient use of nutrients Reduced Risk of Run-off
Water	Invest €7,750 in water 20 troughs @ €200 1500m pipe @ €2.5	Cows currently yield 5500 L +10% yield @ €0.1/L profit = €4,400 Benefits in less than 2 years	Increased output/unit of production Increased resource efficiency
Feed	Measured the amount of feed that was being delivered to the cows	Saving by feeder adjustment =€3,300	Improved feed efficiency Reduced GHG emissions
Inputs & Waste	Reduce inputs by reducing gap between finishing and sales by 3 days per lamb by accurately knowing when animals are finished Spend = €2,800	€4,400 saving per year	Increased efficiency per unit of production

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National Soil Fertility Status and Trends

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Introduction

Emerging trends show that soil fertility levels are declining as a result of the reduction in fertiliser usage in recent years. This is occurring across all farm types. Currently, data from soil samples analysed by Teagasc, indicate that only 1 in 10 grassland soils have the optimum balance of phosphorus (P), potassium (K) and pH status (i.e. Index 3 for P & K, and pH >6.2, Figure 1), with tillage soil fairing slightly better at 12%.

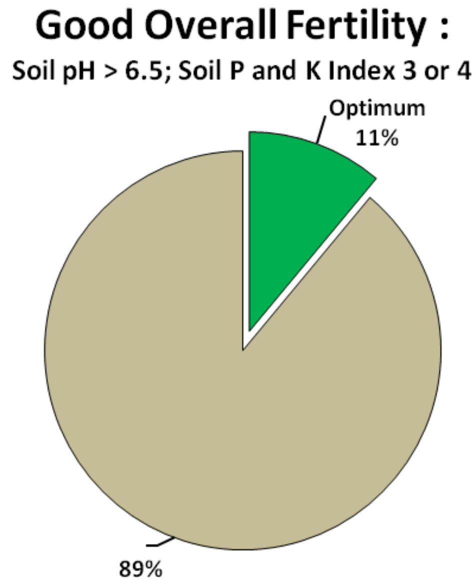

Figure 1. Percentage of grassland soils tested with good overall fertility in 2014.

Soil pH and Lime

Currently, approximately two thirds of soils nationally have sub-optimal pH status. Results from Teagasc show the majority of soils have had lower than desired soil pH status for a number of years indicating that there is a requirement for lime applications on most farms (Figure 2). These soil test results indicate a large requirement for lime on dairy and drystock farms (65% and 70% soil tested have pH <6.2). On tillage farms 59% soils have close to optimum soil pH. Lime has a major role in regulating nutrient cycling in soils. For example, grassland soil maintained at the optimum pH can release up to 80 kg/ha/yr of N from the soil. Low soil pH can negatively affecting the efficiency of freshly applied fertiliser P and K availability and limit the availability of nutrients applied in organic manures.

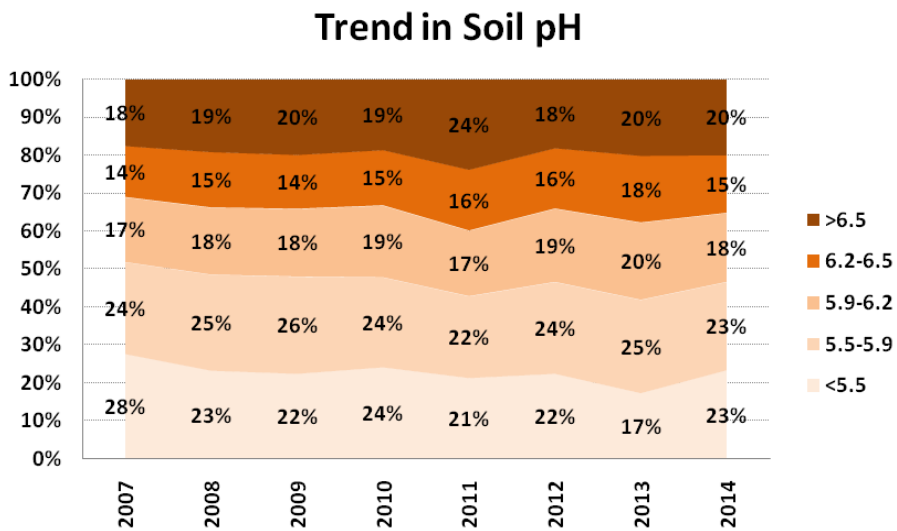

Figure 2. Percentage of all soils tested falling within defined soil pH ranges between 2007 and 2014.

Phosphorus (P)

Since 2007 the proportion of soils tested, across all farming enterprises, with low soil P fertility (i.e. P index 1 or 2) have increased to approximately 55 % in 2014 (Figure 3). A sharper decline in soil P fertility is shown between 2008 and 2012, most likely triggered by the lowest national P fertiliser sales recorded in 2008 and 2009 for the previous two decades. This overall trend reflects the soil P fertility status on dairy, drystock and tillage farms, and indicates a serious loss in potential productivity for the majority of these farming systems. Currently, approximately 1 in 4 of the soils tested has the target soil P fertility status (i.e. P Index 3) with the remaining ~20% of soils tested having above optimum P levels.

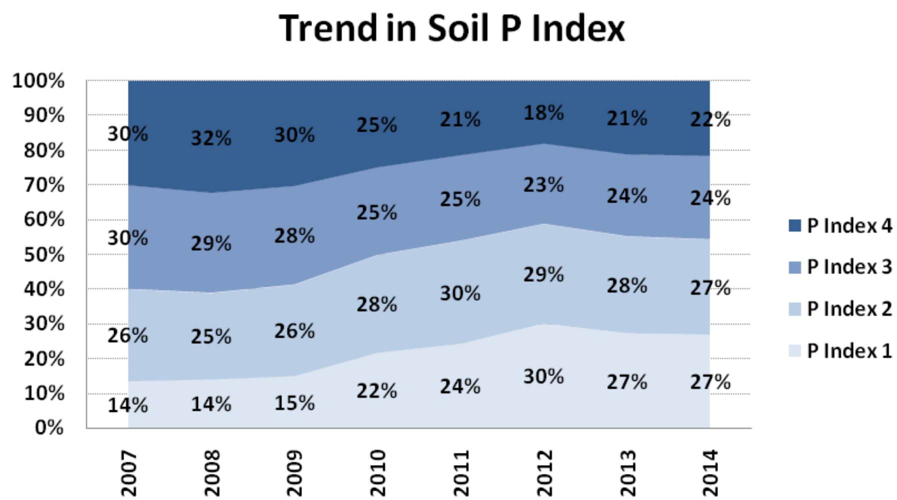

Figure 3. Percentage of all soils tested falling within each soil P index (1-4) between 2007 and 2014.

Potassium (K)

This analysis shows that the trend in soil K status across all faming enterprises broadly mirrors that for P. In 2014 half of the soil samples tested by Teagasc had low soil K status (i.e. K Index 1 or 2). The soil test results indicate a sharp increase in soils with low K status on drystock and dairy farms, between 2008–2011 (i.e. samples with K index 1 or 2), however, this trend has stabilised and is showing signs of reversing in recent years. The soil K status on tillage farms remained relatively constant over this period with currently 55% of soils with good K status (K Index 3 or above).

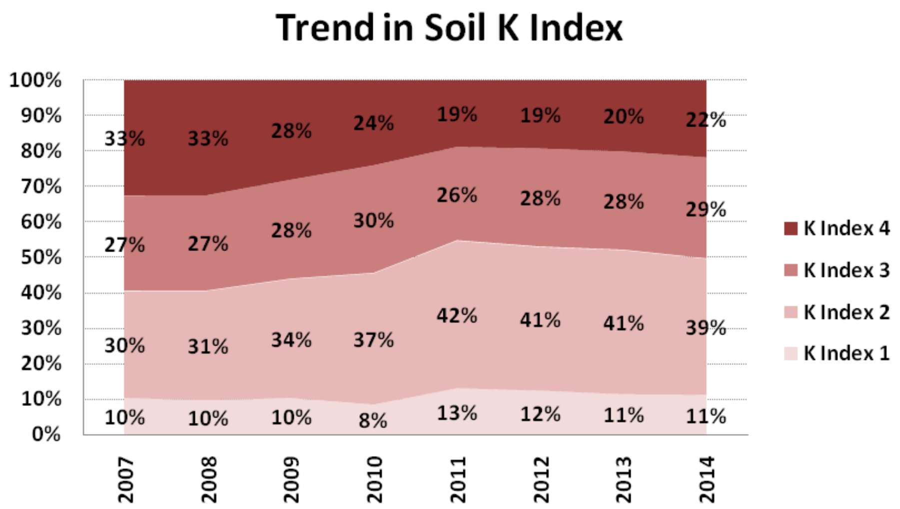

Figure 3.Percentage of all soils tested falling within each soil K index (1-4) between 2007 and 2014

Overall

- A very small proportion of soil samples tested show good overall soil fertility (only 10% for grassland and 12% for tillage).
- Only 35% of soils tested with pH greater than 6.2.
- Approximately half of soils tested had low P (54%) and K (50%) status (P index 1 or 2) in 2014.
- Very rapid declines in soil P and K levels between 2008 and 2011 appear to have stabilised and there are indications of improvement.
- Soil fertility on tillage farms appears to be somewhat better than on grassland farms. However, when declines in soil fertility occur, they appear to be more rapid on dairy farms compared to tillage and drystock farms.