THE FERTILIZER ASSOCIATION OF IRELAND

Proceedings of Spring Scientific Meeting 2020

"Farming in a Low Emissions Environment"

4th February 2020

Horse and Jockey, Thurles, Co. Tipperary

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Contents

ASSAP – a Collaborative Industry Approach to Improving Water Quality

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Introduction

In Ireland, all water policy and management is directed under the EU Water Framework Directive. Under this directive, Ireland has been set a target of achieving 'good status' for all waters in Ireland. However, despite a lot of good work over the last 20-30 years we are falling short in achieving this target and water quality has declined slightly in recent years. The recent EPA Water Quality in Ireland 2013 – 2018 report showed an overall decline in water quality in Ireland. The report highlights that 52.8% of surface waterbodies are at good or high status, down from the 55.4% recorded for the 2010-2015 period. The main area for concern is rivers where water quality has declined by 5.5% over this period. Although overall water quality in Ireland compares favourably to the EU average (40%), meeting objectives under the Water Framework Directive; all waterbodies must achieve good status by 2027, will make the successful implementation of the national River Basin Management Plan (RBMP) all the more crucial. Ireland's response to challenges around water quality is set out under the national RBMP. This plan is renewed every 6 years. The first RBMP did not deliver the level of improvement in water quality expected and subsequent RBMP must achieve more.

National strategy for improving water quality

Three key learning's from the first plan were used to shape a new approach for the second RBMP, these were;

- inadequate governance structures resulted in no clear leadership or mechanisms for delivery,
- multiple river basin districts led to disjointed and ineffective planning and implementation,
- targets and objectives were too ambitious and were not founded on a solid evidence base.

Ireland's 2nd cycle river basin management plan was published in April 2018. Its key innovation is a change in philosophy to move away from dependence on the regulatory-based 'one size fits all' approach, towards being more collaborative, and identifying and implementing 'the right measure in the right place', whilst supporting local communities to get involved in protecting their water resources. Three new interlinked teams were established to progress actions in 190 priority areas (priority areas for action (PAA's)). These investigate the issues at a local scale, collaborate with other public bodies and farmers to have specific measures implemented, and engage with the public and landholders.

This has given rise to the establishment of a new collaborative approach to improving water quality. An industry and stakeholder collaboration has resulted in the Local Authority Waters Programme (LAWPRO) and Agricultural Sustainability, Support and Advisory Programme (ASSAP) being created to provide evidence based approach to pressure identification and farmer focussed advice in 190 priority areas for action (PAA's) as shown in figure 1. The ASSAP is supported by the DHPLG, DAFM, Local Authorities, Dairy Processing Co-Ops, Farming Organisations and Teagasc. The agricultural industry is central in this initiative with support from all the main farming organisations. The focus of the initiative is to provide a free and confidential advisory service to farms located in river catchments identified as having agriculture as the main pressure on water quality (PAA's as shown in Figure 1). Teagasc are providing 20 advisors and the dairy processing Co-Ops are providing 9 advisors to the programme. Scientific support is also provided by Local Authority Waters Programme (LAWPRO).

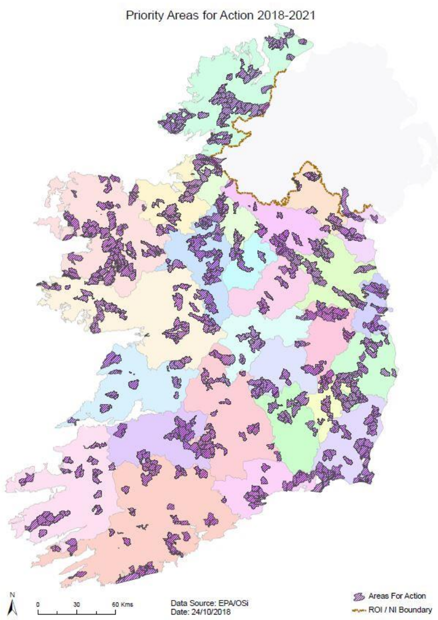

Figure 1. Locations of 190 priority areas for action across Ireland

Agricultural Sustainability Support Advisory Programme

LAWPRO have deployed a catchment assessment team of 60 scientists across the country to assess the PAA's in detail and identify the significant pressures in each PAA. This group communicates the detailed information about the PAA to all of the stakeholders across the local community including agricultural and non-agricultural land-owners and businesses. Where an agricultural pressure is identified the farmers in the area will receive the offer of a free farm visit from an advisor under the ASSAP programme. This ASSAP advisory visit is confidential and farmers in a PAA can avail of advice to improve water quality on their holding on a voluntary basis.

Implementation of the ASSAP

During the advisory visit the ASSAP advisors assess the farm for any potential issues that could be effecting water quality in the local stream. In general, an advisor assesses the farmyard, nutrient management practices and general farm-land management practices including the use of pesticides etc. At the end of the visit the advisor and farmer agree on where improvements or actions, if any are required, should take place on his farm. This practical advice is designed to 'break the pathway' and prevent nutrients from entering water. A written summary of the advice and actions are provided and a timeframe for completion of improvements and actions is agreed between them.

Picture 1. Heavy rainfall on saturated soils can lead to overland flow of phosphorus and soil particles.

What common issues have been identified on farms?

ASSAP advisors have been actively visiting farms since April 2019 and are currently working with farmers in 68 PAA's and have completed 1181 farm assessments and provided plans to farmers. Diffuse losses are the losses of phosphorus (P), sediment and nitrogen (N) coming from the landscape make up 75% of the issues impacting water quality (Figure 1). Phosphorus and Nitrogen appear to be contributing to 48% of the issues nationally. Sediment is also a very significant pressure and is a contributing factor in 27% of the PAA's and is greater than was expected. However these losses can be greatly reduced in many cases by implementing improved management practices. A wide range of issues have been identified on farms with advisors offering practical advice on mitigating these potential areas of nutrient and sediment loss to waters (Table 1).

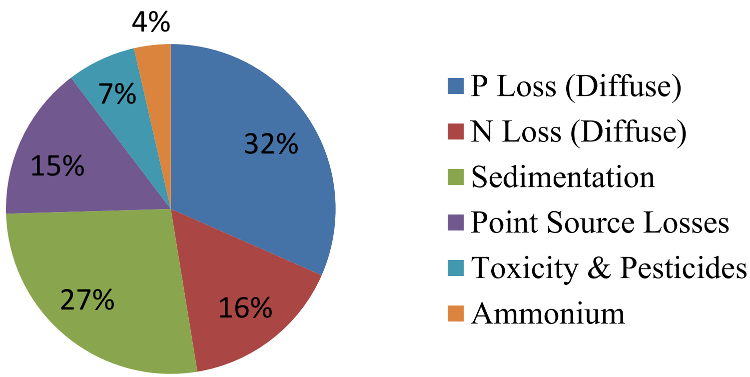

Figure 2. Pressures Identified in PAA's

Table 1. Most frequent water quality issues identified on farms and associated actions for mitigating nutrient or sediment losses

Phosphorus & sediment loss through overland flow	%
Management of Critical Source Areas (CSA's)*	35
Riparian Buffers - Fenced/Unfenced	28
In-field grass buffers	15
Implementation of Nutrient Management Plan (NMP)	7
Establish field boundaries and hedges	4
Other actions	11

Preparation & implementation of nutrient management plans	%
Precision application of nutrients at correct rate	51
Informing and educating farmers	39
Avoid nutrient application at high risk times	4
Avoid nutrient application to high risk places (CSA's)	2
Other Actions	4

Livestock Drinking Points & Stream Fencing	%
Prevent livestock access to waters	75
Informing and educating farmers	20
Other Actions	5

Buffer Zones	%
Adhere to buffer zones and safeguard zones	76
Riparian Buffers - Fenced/Unfenced	8
Avoid nutrient application at high risk times	5
Other Actions	11

Organic Manure: Application Timing, Location & Method	%
Avoid application at high risk times	45
Avoid application at high risk places (CSA's)	22
Informing and educating farmers	16
Adopt latest manure application techniques	9
Precision application of nutrients at correct rate	5
Other Actions	3

Critical Source Areas (CSA's) – these are areas of the farm that can have a direct impact on water bodies due to the high connectivity of the area with water.

How can farmers reduce diffuse nutrient and sediment losses?

Some of the main issues identified on farms indicate that diffuse P, N and sediment pressures need further attention. How land is managed at critical times of the year impacts water quality. It also indicates that the management of nutrient inputs on farms is crucial for preventing nutrient losses to waters. Farmers are being asked to implement simple practice changes and put in place some low cost actions to mitigate the potential for nutrient and sediment losses. The use of buffers, both fenced and unfenced, and avoiding livestock access to waters are key actions in the effort to improve water quality.

The management strategies may be different for P and sediment, which typically run-off the surface of the soil compared to N, which is more prone to leaching with draining water through the soil. For example to reduce P and sediment losses that typically occur when water is running off the land periods of heavy rainfall the implementation of appropriate buffer strips and prevention of livestock access to streams/rivers will help to reduce such losses from occurring. One very effect way to reduce P and sediment losses across the farm is to avoid spreading nutrients and improve the management of wet areas with close proximity to the stream or rivers. These critical source areas (CSA's) are more prone to nutrient and sediment loss during wet weather than the surround land or fields and small changes to management in these areas can help greatly to reduce impacts on water quality.

Picture 2. Appropriate buffers will help protect water from nutrient and sediment losses.

Improving the overall nutrient recovery and nutrient use efficiency on the farm, particularly nitrogen fertilisers and slurries, will be crucial to reducing nitrate losses to waters in more intensively farmed areas. Farmers need to be particularly careful when using nitrogen in the early spring and late in grazing season as growth rates are lower and excess nitrogen can be more easily lost to rivers, lakes and groundwater when rainfall is high. In tillage areas growing cover- or catch-crops in autumn will mop up surplus nutrients remaining in the soil post-harvest, help bind soil and prevent sediment losses during period of heavy rain in winter and help to improve soil organic matter and soil quality in the longer term.

Conclusions

The ASSAP programme is collaborative and the funding and support received from DAFM, DHPLG and the dairy industry has been critical to allow a new approach to enabling local landowners to engage positively in seeking solutions to local problems with the support of a confidential advisory service. Support from the farming organisations for the programme has been very strong and this is vital in communicating and informing farmers about the ASSAP programme and its key messages.

Water quality has improved by 16.7% in priority areas for action (figure 1) where engagement between ASSAP advisors and farmers has occurred. This is very encouraging and shows that farmers are playing their part in improving water quality in Ireland. In 2020 and 2021, the ASSAP will continue to provide farmers with the help and advice they need to increase the sustainability of their farming practices and systems with the hope of further improvements in water quality in the years to come. It is in every ones interest to work together to improve Irelands overall water quality. This will have many benefits across the local community and will help with achieving Ireland’s obligations under the Water Framework Directive. It will also help to strengthen agriculture by reinforcing our green image as food producers and underpin the future development of sustainable Irish agriculture.

Sufficient available Potassium – Essential for Crop and Grass Production with Good Nitrogen Use Efficiency

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Introduction

The principle of balanced nutrition for crops and grass is supposedly well known, yet many crops still fail to yield to their full yield or quality potentials due to nutrient imbalances. Fertiliser nutrients are not applied to make plants grow; it is a lack of an adequate supply of one or more nutrients, which prevents crop plants from achieving their yield potentials. Thus, fertilisers are applied to remove any nutrient constraints, not to 'make plants grow'.

However, the provision of some nutrients needed by crops in relatively large quantities, particularly nitrogen, presents greater management challenges than others because they are not well retained in soil in their mineral states and the mineralisation from their organic forms can be difficult to predict. Thus the management of nitrogen application rates and timings is liable to dominate nutrient planning at the expense of consideration of the other essential nutrients, which may be assumed to be available from soil reserves. As a result of this focus it is sometimes claimed that 'nitrogen is the most important nutrient'. This is clearly incorrect as all plant nutrients are essential; it may be true to say that nitrogen is the most difficult to manage, and may be likely to be the most limiting of a full yield, but it is no more important to the crop than any of the other nutrients.

This is not to undervalue the importance of the careful planning of a nitrogen fertiliser and manure strategy, but to plan nitrogen rates for an expected high yield without confirming an adequate availability of the other essential nutrients can lead to the application of more nitrogen than the crop is able to use, if other nutrients become limiting.

The proportions of the different essential nutrients required by crops and grass is illustrated in Figure 1, in which the 'full yield' column represents the percentage contents of the dominant nutrients. The values are those from an oat crop at maximum biomass and will be similar for other cereals and grasses. A less productive oat crop is represented by the 'half yield' column, which contains the same nutrients in the same proportions as the 'full yield' crop, but with smaller quantities. If the smaller yield had been caused, for example, by a limited availability of potassium (K) to the crop then the requirements for the other nutrients are less, this being notably apparent for nitrogen (N).

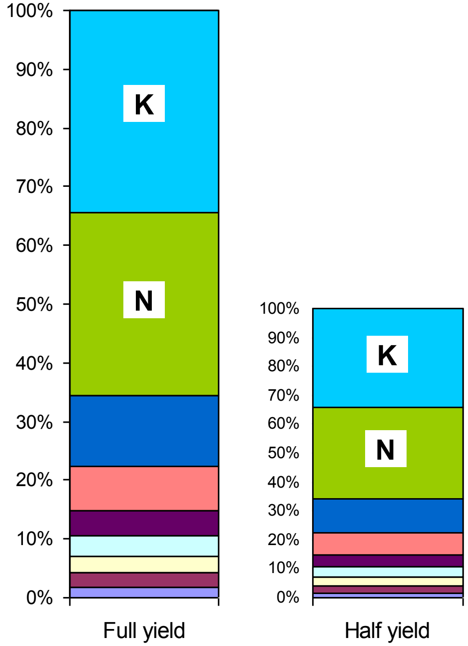


Figure 1. **The proportions of the mineral nutrient content of plants remain relatively constant, irrespective of yield, as illustrated here for some nutrients in the above-ground fresh biomass of oats. Thus if yield is limited by a shortage/ deficiency of one nutrient (e.g. potassium, K), the requirement/uptake of the others (e.g. nitrogen, N) is reduced proportionally.**

Soil potassium reserve

Management of the nitrogen supply for crops and grass presents challenges because mineral soils will release only moderate quantities of nitrogen to the growing crop, thus requiring careful calculation of the amount needed from fertiliser or manures. Nitrogen which is surplus to crop needs will be lost, representing both a financial and environmental cost.

Potassium on the other hand is well buffered in most mineral soils and the management of this nutrient is less challenging, which perhaps has led to it receiving less attention. The recent trend in soil K Indices is shown in Figure 2 and it is of note that the results for 2018, which diverge somewhat from the trend line, are nevertheless almost exactly the same as the 12-year average values. The data indicate that about 50% of soil analysis results for potassium are below the recommended optimum reserve status of K Index 3. This implies that crops and grass grown on these deficient soils will be unlikely to achieve their full yield potential and will be at risk of sub-optimal nitrogen use efficiency.

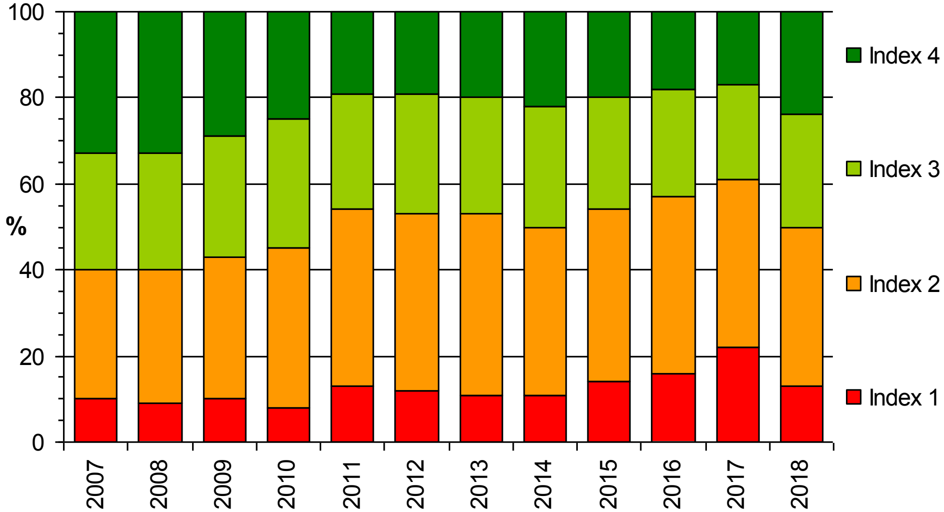


Figure 2. Trends in soil potassium (K) indices in Ireland.

If the soil K Index is maintained at Index 3 it is likely that the soil will be able to release from its exchangeable reserves sufficient potassium to fully satisfy crop requirement. In such situations the application of an amount of potassium from fertiliser or manures equal to the quantity removed in the harvested crop or grass will maintain this optimal soil K status.

The importance of potassium

Potassium has major effects on yield and quality as well as on the general health and vigour of a crop. It is very important in the relationship between water and crop growth because it helps regulate the amount of water within the crop. Plants with enough water remain turgid and upright provided the individual plant cells contain sufficient solutes to maintain osmotic pressure within the cell sap. The solute most plants use is potassium, which explains why it is vital for maintaining the turgidity (rigidity) of plant cells and tissues. When there is insufficient potassium to maintain osmotic concentration in new cells, leaf expansion and stem elongation become too slow during the early stages of growth for the leaf canopy to expand and rapidly cover the ground. This results in inefficient interception of sunlight and photosynthetic production of assimilates required for the crop to grow rapidly. Also, potassium has a further role within the plant that is vital for achieving optimum yields. It is required for the transport of sugars from the leaf, where they are produced, to the growing regions of the plant and to storage organs such as grain in cereals and the tubers of potatoes where they are converted to starch.

Crops grown on soils with too little plant-available potash become deficient in potassium resulting in reduced yields. Without sufficient potassium, crops fail to use water efficiently and consequently become more seriously affected by water stress in periods of drought. Plants also use N less efficiently and are less able to handle stress caused by frost, heat, water-logging and wind. Thus it is essential to bring soils to the target Index for plant-available potassium (exchangeable K) and then maintain this level by replacing the amount of potash removed each year in the harvested crops. To ensure that this approach is maintaining the target Index, soils should be sampled and analysed for potassium every 4/5 years.

As was apparent in Figure 1 the potassium content of a crop is of the same magnitude as that of nitrogen, and is frequently greater. The high uptakes of both potassium and nitrogen by a wheat crop is shown in Figure 3; these proportions and quantities will be similar for grass silage.

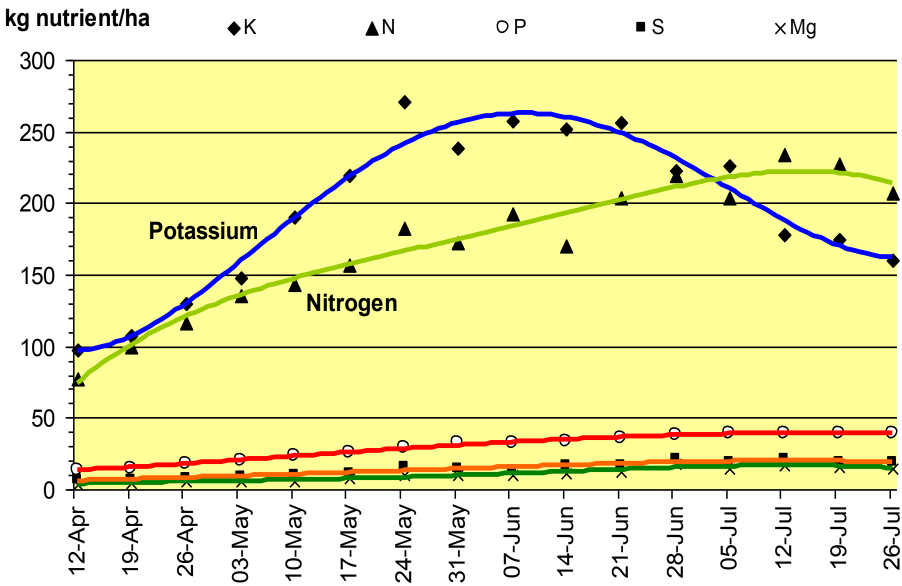


Figure 3. The weekly pattern of cumulative macronutrient uptake by an 8.8 t/ha wheat crop illustrating the large quantities of nitrogen and potassium in the growing crop.

It is important to distinguish between the potassium content (uptake) of a crop and the quantity removed at harvest (offtake). High uptakes of both potassium and nitrogen are shown in Figure 3, and the resulting nitrogen offtake in grain protein is relatively high at 64% of the total uptake, whereas the potassium offtake in the grain is much lower at only 15% of the maximum uptake. An offtake, and therefore a replacement recommendation, of only 40 kg K/ha for the 8.8 t/ha wheat grain crop (Figure 3) might suggest that potassium is not a major nutrient for this crop. However, when the actual uptake of potassium is seen to be potentially greater than 250 kg K/ha it is clear that it is essential to ensure an adequate availability of this nutrient.

The reason for the very high potassium content in the green tissue of crops is because large amounts are needed in the tissue water (i.e. the plant sap), as discussed earlier. As a crop grows the expansion of the number and area of the leaves is driven largely by nitrogen, which enables the production and expansion of the cells in the leaves; an illustration of a leaf cell is shown in Figure 4. The major volume of the cell is occupied by the vacuole, which contains water and is surrounded by a semi-permeable membrane. This vacuolar water contains potassium in solution (6-7.5 g K/L) which acts as the osmoticum, causing water to enter the vacuole thereby increasing the internal pressure and ensuring that the cell remains turgid (rigid). This is necessary if the leaf is to remain upright and so able to intercept light effectively, enabling efficient photosynthesis.

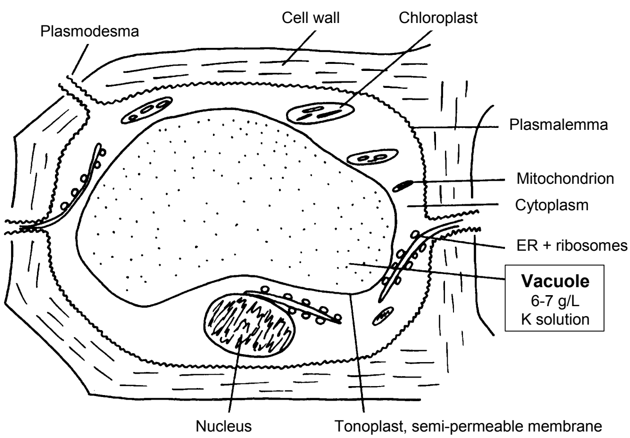


Figure 4. Simplified representation of a plant leaf cell, showing the vacuole.

As these leaf cells are produced and increase in size so the volume of the vacuole increases; a doubling of the length of a cell will increase its volume 8-fold. A recommended amount of nitrogen will be applied in order to enable the crop to grow to its full potential, but the cell division and expansion for this will only be possible if sufficient potassium is available from the soil reserves to supply the vacuolar requirements. Nitrogen use efficiency therefore depends on the soil having enough available potassium.

The effects of the application of an adequate versus inadequate rate of nitrogen of the shoot biomass of a spring barley crop can be seen in Figure 5a, where the above-ground dry matter is 10-12 t/ha where 144 kg N/ha are applied compared with only 6-8 t/ha with an inadequate 48 kg/ha. Figure 5b shows the significant effect this biomass increase has on the quantity of tissue water (sap) which is in the two crops: the crop receiving the higher nitrogen rate contains about 10 t/ha more tissue water. This extra tissue water will contain approximately an extra 70 kg/ha more K than the crop receiving the lower nitrogen rate.

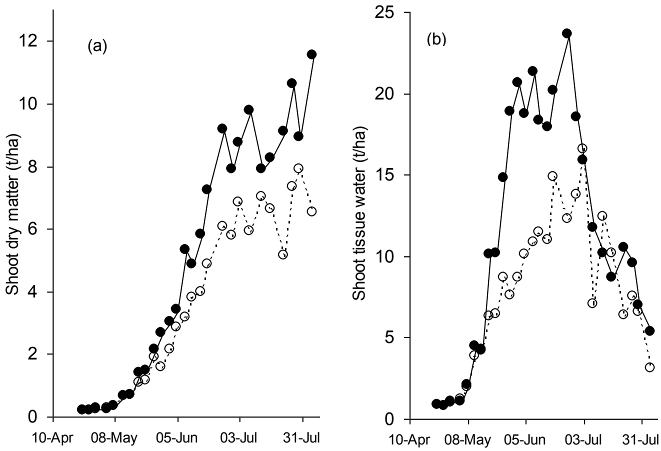


Figure 5. Patterns of dry matter accumulation and tissue water content of spring barley shoots with 48 (○) and 144 (●) kg N/ha (Rothamsted).

Crop response to potassium

It has been said that some growers are reluctant to apply much potassium because they 'do not see a response'. Visual deficiency symptoms are only likely to be seen if soil reserves are very low, i.e. in Index 1 (see Table 1).

Table 1. The soil Index system for the classification of the potassium status of a soil from sampling and analysis, with interpretation.

Index	Index description	Crop response to potassium
1	Very low	Definite
2	Low	Likely
3	Medium/adequate	Unlikely/tenuous
4	Sufficient/high	None

However, yield depression and other symptoms of a shortage of potassium are also likely if the soil is in K Index 2. This effect is often termed 'hidden hunger' because symptoms are rarely visible, see Figure 6. Standard recommendations are therefore to maintain soil K reserves in Index 3 to ensure an adequate availability of potassium for the growing crop. Keeping soils at Index 3 also provides insurance against the risk of difficulty in taking up sufficient potassium under severe adverse conditions, such as soil compaction or drought.

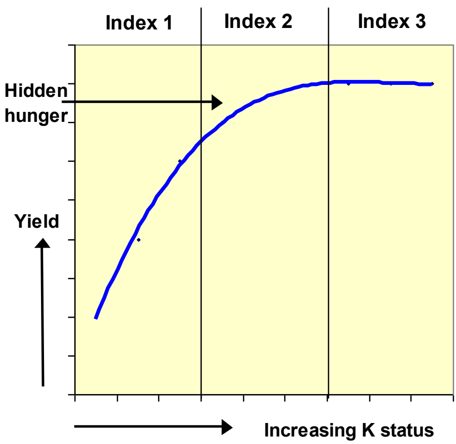


Figure 6. A typical crop 'yield response curve' to an increasing quantity of available potassium in the soil.

Having achieved an Index 3 status it must be maintained by applications of nutrients, from manures and/or fertilisers to replace the nutrients removed in the harvested crop. When grown in a phosphate or potassium deficient soil crops are usually unable to reach the full potential performance possible from an Index 3 soil even if additional fertiliser is applied for that crop. However, for most field crops and grass little advantage is likely from maintaining soils at an Index above 3 or 4.

Effect of potassium on nitrogen response

As was observed in the Introduction an adequate availability of all essential nutrients is required for balanced nutrition and optimal crop and grass production; within this the two nutrients required in the greatest quantities are nitrogen and potassium (see Figure 1). The relationship between these two requires particularly careful management because of the quantities involved and as an imbalance or shortfall in availability of one will alter the need for the other. If a sub-optimal rate of nitrogen is applied then the requirement for potassium will also be lower than optimal and less potassium will be taken up from the soil reserve – apart from a reduced level of production this does not present a problem as the 'surplus' of potassium is safely retained in most soils.

However, if a rate of nitrogen is applied to achieve a full potential yield but there is an insufficient supply of available potassium, then the full yield cannot be achieved and some of the nitrogen will not be able to be used by the crop, leading to a lower 'nitrogen use efficiency' (NUE). This surplus nitrogen will not be held in the soil like the potassium but will be lost to the environment.

Table 2 illustrates the lower yields of grass being achieved where the K Index is low, with only a small increase when the N rate is doubled. This is compared with the much better yield at the low N rate where the K supply is good, with this yield being able to increase by almost 40% to 11.8 t/ha with the extra N, unconstrained by any lack of available potassium from the soil.

Table 2. Interaction between nitrogen and potassium on the yield of grass. (Park Grass experiment, Rothamsted 1965-1968).

	N applied per cut	
K Index	40	80
	average annual yield, t/ha DM	
1	5.8	6.5
4	8.5	11.8

Table 3 again shows the poorer yield where the soil K Index is low, despite adequate nitrogen, and also shows that the application of fresh potassium cannot raise the yield to that achieved on the high K Index soil. The table further illustrates that provided the potassium supply is sufficient, the application of extra potassium does not lead to any further yield increase. However, in this K Index 3 situation an application of potassium will still be required to maintain this recommended soil K status.

Table 3. Effect of different soil potassium (K) status on winter wheat grain yield and the effect of freshly applied K to a crop well-supplied with N.

Soil K index	**Fresh K, kg/ha**	
	0	83
	Grain yield, t/ha	
3	11.0	11.0
1	6.8	9.6

Removal of potassium in harvested products

As has been seen, a high tissue water content in a crop is directly associated with a high potassium content. This has implications when calculating the quantity of potassium which should be applied as a maintenance dressing to ensure that the soil does not become depleted. Any plant material which is green at harvest, such as grass silage or whole-crop for example, will remove potentially large amounts of potassium, as indicated in Table 4. The wilting of silage to evaporate some of the tissue water will not alter the quantity of potassium removed from the field, which for 3 cuts of silage can be over 400 kg K/ha. A cut of silage taken in late summer after grazing can remove approaching 100 kg K/ha which, if not replaced by fertiliser or slurry/manure, will significantly deplete soil potassium reserves of these grazing fields.

A relatively high removal of potassium is also found in harvested products which have senesced after having been green tissue, such as straw, although the quantity will be reduced by rainfall just prior to and post-harvest. Harvested grain has a relatively low potassium content, not having been green photosynthesising tissue with its high water and potassium content. However, this relatively small potassium offtake in grain is in contrast to the large uptake required for the biomass of the crop which produced the grain.

Table 5 provides a guide to the average potassium content per fresh-weight tonne of some harvested products, as a guide to offtakes.

Table 4. Yields and nutrient removals of some grass and fodder crops as measured by Kingshay Farming Trust in a three year study (Source: PDA).

	Fresh yield t/ha	DM yield t/ha	Nutrient removal, kg/ha N	P	K
IRG Silage					
Cut 1	34	5.2	126	21	**190**
Cut 2	31	5.5	115	18	**164**
Cut 3	19	3.8	79	12	**90**
Cut 4	6	1.0	52	2	**28**
Total/year	90	15.5	372	53	**472**
PRG/white clover					
Cut 1	31	5.0	121	18	**173**
Cut 2	27	4.5	105	15	**158**
Cut 3	18	3.2	81	10	**96**
Total/year	76	12.7	307	43	**427**
Wholecrop wheat	39	14.4	181	30	**176**
Maize (1 year only)	33	8.9	130	24	**179**

Table 5. An indication of the potassium (K) content per fresh-weight tonne of some harvested products (Source: PDA).

	Grass silage (25% DM)	Hay	Cereal grain	Oilseed rape seed	Peas (dry)	Beans	Potatoes	Cereal straw (winter)	Cereal straw (spring)	Oilseed rape straw	Pea & bean straw
kg K/t fresh weight	5.0	15	4.6	9.0	8.0	10	4.8	8.0	10	11	13

Conclusions

Crops and grass have large requirements for both nitrogen and potassium and the efficient utilisation of nitrogen depends on the availability of enough potassium for the growing crop. The risk of poor crop performance and a low NUE are generally avoided on soils maintained at optimum K status (K Index 3).

Farming in a Low Emissions Environment – a Dairy farmer's perspective

John and Martina Molyneaux[1], and Ger Courtney[2]

[1]Dromcollogher, West Limerick
[1]Teagasc advisory, Killarney, Co Kerry

Introduction

John & Martina Molyneaux dairy farm in west Limerick and have three children. They run a jersey-cross herd of a 100 cows and are all spring calving. The EBI of the herd is €160. Their farm consists of a 35ha home block which is the main milking platform for the dairy herd on free draining clay soils with another 6.5ha owned land 1 mile away. They also rant 8ha with is a further 8 miles away. Whole farm was stocking at 2.6 LU/ha in 2019. All male calves are typically sold at 2 weeks old and sufficient dairy calves are kept as replacement stock for the diary herd. In 2019 the dairy herd achieved 472 kg milk solids /cow (1382 kg MS/ha) and the milk was sold to Kerry Agribusiness. The annual rainfall in this area of west Limerick is 1050 mm on average and its possible to achieve 280 days at grass for the grazing season, however, in 2019 the herd was as grass for 270 due heavy rainfall in autumn and earlier winter housing. John is involved in 2 discussion groups, the local Teagasc discussion group and the Pathfinders discussion group and the farm is also part of the joint Kerry Agribusiness -Teagasc monitor farm program for the last 4 years.

For John and Martina the main driver for milk output and revenue generated on the farm is the growth of quality grass to feed the dairy herd cheaply and sustainably. Grass growth in measured in each paddock weekly and records are entered into Pasturebase Ireland grass recording and budgeting programme to ensure that quality grass is in front of the cows from early February to mid-November. In 2019 John took 49 grass measurement walks and the average grass grown across the farm was 14.5 tonnes/ha of grass dry matter. Some of the key details of our farming system over the past three years as outlined in Table 1.

Table 1. Molyneaux farm profile and key performance indicators for 2019

Farm Details	2019	Livestock Numbers	2019
Total land area	48.8 ha	Cows	100
Owned land	40.8 ha	Replacements 0-1 yr	38
Leased land	8 ha	Replacements 1-2 yr	22
Milking platform (MP)	35 ha	Herd EBI	€160
Farm Stocking rate	2.6 LU/ha	6 week calving rate	89%
Milk solids /cow	472 kg	Days at grass (grazing)	270
Milk solids /ha	1382 kg/ha	Grass production MP	14.5 t/ha
Concentrate feed /cow	500	N Fertiliser Use	236 kg/ha

Investing in Soil Fertility

Good soil fertility is crucial to the farming system and improving soil fertility has been a key area of priority investment on the farm. According to John "soil fertility has be right to allow us to grow over 14 tonnes of grass in a sustainable manner. In 2020 we plan to consolidate our business by dropping the rented ground and contract rear the calves for the first time. As only Martina and myself run the farm, this will allow us to have time to concentrate on being more efficient on our own land and have a better quality of life. With the improvements we have made in soil fertility we are in a position to fully feed the herd without having to buy in silage and with minimal supplementation only".

As part of the KerryAgribusiness/ Teagasc programme soil samples are taken on the farm every year. Progress in the key areas of soil fertility management – pH, P & K are shown in the colour coded map comparison 2016-2020 (figure 1). "We feel annual soil testing is vital to keep on top of soil fertility changes that happen over a period where were concentrating on soil fertility build-up". Since 2017 the percentage of paddocks on the farm that have optimum soil pH, P & K levels has increased from 0% (2017) to 60% (2019). This includes the low soil test index land that was leased this year. The home farm has close to optimum soil fertility overall with over 90% of the land that we will farm in 2020 having optimum soil fertility. This progress in soil fertility improvement was achieved using long-term liming programme and application of build-up rates of P & K fertilisers over the last four-year period. "It took persistence and investment but it's the foundation of our grass based system for the next phase of our farming career".

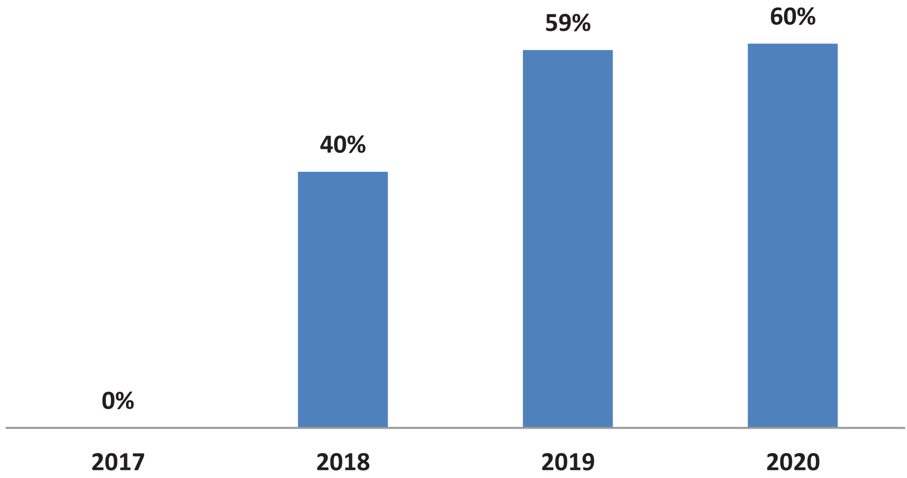


Figure 1. Proportion of the Molyneaux farm with good overall soil fertility (i.e. optimum soil pH, P and K levels) from 2017 to 2019.

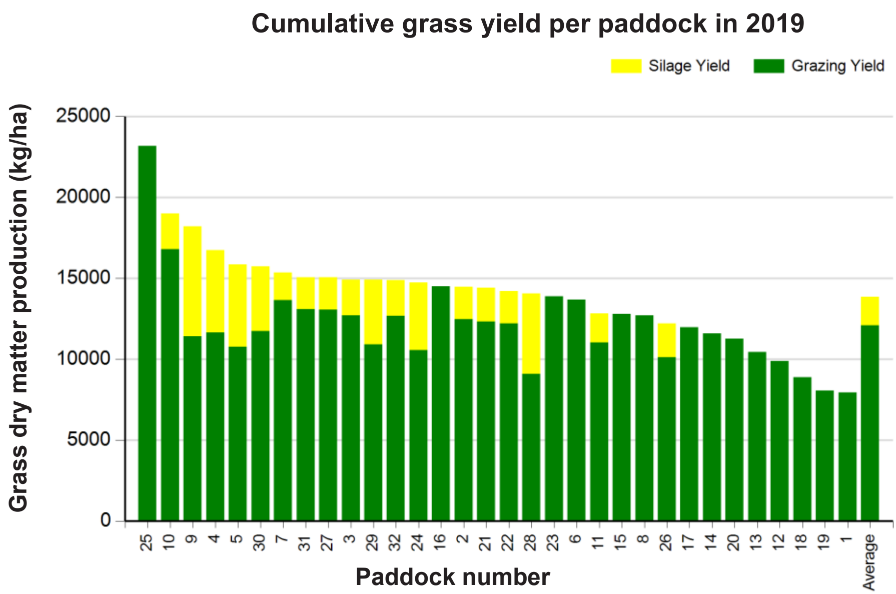
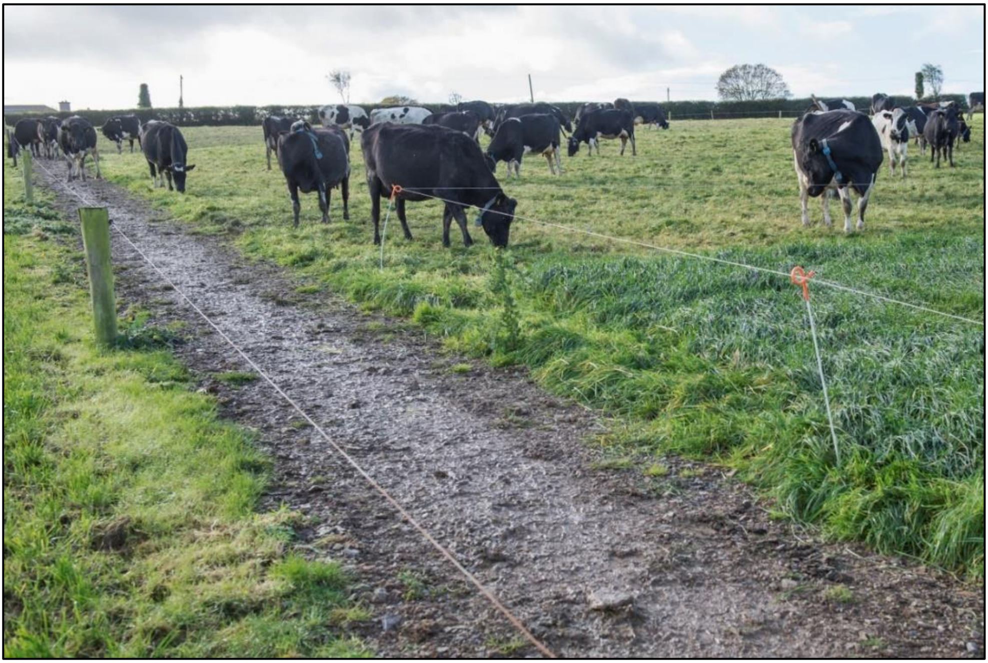


Figure 2. Grass dry matter production in each paddock on the Molyneaux farm in 2019. Total grass production for each paddock is broken down into grazed grass yield and silage yield.



Grass production

In 2019 the grass production on the milking platform of 35 ha averaged 14.5 t DM /ha. Grass production in Spring 2018 was exceptionally good and by the Monitor Farm Walk which was held on May 22nd the milking platform had grown 3.4 tonnes grass DM/ha with a stocking rate of 3.5 cows/ha with a total of 210kgs concentrate feed per cow. Annual concentrate feed was 500kgs/cow of low protein concentrate. No other forage was purchased in 2019 which was a relief after an expensive 2018 when the farm was hit hard by drought and forage and concentrate feed needed to be purchased.

Grass reseeding

A small number of paddocks on the farm are keeping down the average grass production figures and these are chiefly those that were reseeded in May 2018. Post reseeding these paddocks were not fit for grazing until late July and the total grass production recorded for the year was less than 10 tonnes/ha. A programme of grass reseeding is the next phase of grassland development n the farm having corrected soil fertility. The plan is to reseed up to 15% of the area each year. So far John has only included clover at 1.2 kg/acre in grass seed mixes used however, he is open to discussion on increasing clover content over the next few years. Eliminating weeds post reseeding and over-sowing with clover the following year is one plan that John is considering. As grass production and management has improved, John says “we are conscious that the removal of surplus bales can quickly deplete reserves, so in 2018 we blanket spread MOP fertiliser (50% K) on all the ground that silage was taken from during the year. The challenge is to follow such a K fertiliser programme at the end of the season when ground conditions in autumn /early winter are difficult in some years.

Nitrogen fertiliser use

The nitrogen fertiliser use across the whole farm was 11,505 kg N or on average 236 kg N/ha. Over 50% of the N fertiliser applied on the farm was applied in the form of protected-urea. John says "the 2019 season was our first year using protected-urea and we are very happy with the outcome, seeing no negative impact in our three week grass growth cycle and our annual production at 14.5 t dry matter/ha. Overall, the nitrogen use efficiency (NUE) on the farm was calculated at 30% which I understand is a good figure for grazing systems and takes into account our total inputs versus total exports of nitrogen. Our high milk protein levels of of3.76% and low concentrate feed use were some of the main factors contributing to relatively high NUE, as well as being self-sufficient for forage to feed all our stock".

Table 2. Breakdown of nitrogen fertiliser sources on the Molyneaux farm in 2019.

Nitrogen Fertiliser Type	Total tonnes used	Total kg N used
CAN (27%N)	0	0
Urea (46%N)	6	2760
Protected urea (46%N or 38%N)	14.25	6015
Compound fertilisers	17.5	2730
Total		**11505**

Role of Slurry

Colour coded maps generated in the Teagasc NMP-Online fertiliser planning programme are used to target slurry applications on the lower P and K index paddocks (i.e. P index 1 & 2) while the grazed grass and silage yield records in the Pasturebase Ireland program were used to identify paddocks with high grass offtake which need higher replacement of P & K, for which the application of cattle slurry is idea. Slurry is spread using low-emission slurry spreading (LESS) method; a dribble bar system is used by the contractor to spread all slurry on the farm over the past four years. John says "we are very happy with the grass growth response and the fact that leaf contamination is greatly reduced encouraging us to remain with this system of slurry spreading in future. As we move towards a maintenance only fertiliser programme slurry will become even more important to maintain our soil fertility levels. In 2019 we used a 2nd cut slurry programme plus protected urea only and grew a great crop of silage at close to 8 tonnes/acre".

Breeding and the right cow for the farming system

The Molyneaux's have focused strongly on selecting high EBI sires for the replacement breeding programme on their herd and have also introduced Hybrid vigour through the use of Jersey sires over the years. The average age if heifers at first calving was 23 months and cow size is important, with a focus on producing medium sized, low maintenance, cows. The dairy herd is consolidating after a bad TB breakdown in 2016, which has resulted in increased herd maturity with 63% of the herd currently at 3rd lactation or greater. The average lactation number in the herd was 5 in 2019 which has led to high milk solids production (472 kg/cow) with good herd fertility. 89% of the herd calved within 6 weeks and the average calving interval was 370 days. The milk composition was on average 3.76% protein and 4.58% butterfat in 2019. Over time this breeding programme and good herd performance has resulted in decreasing (-19%) carbon footprint per kg milk (0.96 kg CO_2 / kg Fat & Protein Corrected Milk in the 2018 Bord-Bia farm sustainability audit .

Energy efficiency

The Molyneaux's aim to be as energy efficient as possible and have installed a plate cooler to reduce the temperature of milk entering the bulk tank and the associated energy costs cooling milk. They also maximise use of night rate electricity to heat water etc. "Variable speed milk and vacuum pumps have been installed in our dairy and this has helped to further reduce electricity costs on the farm".

Space for Biodiversity on the farm

The farm has a high density of natural hedgerows, which have been enhanced with broadleaf trees over the years. John and Martina's future goal is to further manage and enhance these natural farming assets where they exist across the farm.

Farm Profitability

Much attention in placed on monitoring the financial performance of the farm through the use of cash flow budgeting and E-Profit monitor analysis. The net profit dairy /ha (excl. own labour) for the period 2016-2018 is shown in Table 3. As the farm business will be consolidated further in 2020 by reducing leased land and focusing more on the dairy enterprise efficiencies, a net profit €2000/dairy hectare (at base milk price of 30c/l) will be targeted.

Table 3. Farm profitability 2016 to 2018

Year	Net Profit/ha#	Dairy ha's*
2016	€1,625	40
2017	€2,018	49.1
2018	€992	41.3
Average	**€1,545**	**43.47**

Excluding own labour

* Dairy ha's includes the grazing and silage area supporting the cow herd

Future plans for the farm

The farming system developed by John and Martina provides a profitable return on time and investment and a good work-life balance for them and leaves time for their family. The Molyneaux's are conscious the environmental footprint of their farm and impacts of the farming system has on the wider environment. Many of the current management practices adopted on the farm are in keeping with recommendations to reduce carbon emissions from the farming systems.

In future John and Martina plan to maintain all the farming area at optimum soil fertility and to use 100% protected urea and continue to target slurry applications using low emission slurry spreading methods to correct any soil fertility issues. In particular they will pay greater attention to the timing of N fertiliser applications and the quantities applied. They will continue to improve EBI and maximise the number of days their herd is out grazing at grass. They aim to increase their knowledge and understanding of clover so that it can be successfully incorporated into the future reseeding programme. Overall, they will consider and engage with all new technologies that will help to reduce the emissions and nutrient losses from the farming system.

In conclusion, John says "we want to live and work in an environment that is sustainable from an economic, work-life and environmental perspectives, we are willing to make changes and without change we are not playing our part and we intend to do just that".

The Importance of Potassium in Agricultural Soils

Tim Sheil[1,3], Mark Plunkett[2,3], Patrick Forrestal[2] and David Wall[2,3],

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Introduction

Potassium is an essential nutrient for plants, animals and humans. It is one of the major three plant nutrients - nitrogen (N), phosphorus (P) & potassium (K) and is required in large amounts (similar to N) during the growing season. It is a pivotal nutrient in plant structure development and plays a key role in the uptake and efficient use of N. Potassium is a major element and is the eight most abundant mineral in the earth's crust. It occurs in many minerals and salts and due to its solubility it's relatively available. The total K content of mineral soils usually ranges from 0.04 to 3%.

Soils and soil potassium availability

Potassium exits in the soil in a number of different states / pools. Potassium ions move from one pool to the next whenever there are removals or additions of K which change the balance within the K pools. The ability of the soil to supply K very much depends on the transformations between the various liable K forms and the balances with the soil solution. The main pools of K are outlined below;

- "Available K pool" tends to be the smallest K pool in the soil and contains water soluble K for plant uptake.
- "Readily available K" pool replenishes the available K pool many times during the growing season as K is released from the surfaces of the clay particles.
- "Less readily available K" is interchangeable with the readily available K pool.
- "Very slowly available K" pool is made available over time through weathering (clay) and organic matter decomposition processes and this pool of K tends to be very stable.

Soil test phosphorus

The first step to managing soil K fertility is to determine the soil K levels with a soil test. The soil test measures a readily available soil K pool which indicates the soil K supply for crop production It is important to take good soil samples to ensure reliable soil K results for formulating the correct K fertiliser advice appropriate for the crop being grown. On grassland soils ensure that at least 20 representative soil cores are taken from within the area being sampled to the correct depth of 10cm. These 20 soil cores are amalgamated to make one composite soil sample representing the sampling area. More information of correct soil sampling procedure is available in FAI bulletin No 1 https://www.fertilizer-assoc.ie/wp-content/uploads/2015/10/Fert-Assoc-Tech-Bulletin-No.-1-Soil Sampling.pdf

The Morgan's K test measures the labile K pool (available & readily available P) in the soil that indicates plant available K supply. The Morgan's K test has been calibrated, and translated into critical soil test thresholds, for all the major crops produced in Ireland. The Morgan's test is currently the standard soil test used by the agricultural industry in Ireland and is approved by the Department of Agriculture, Food and the Marine (DAFM) for agri-environmental regulations and voluntary farm schemes. This soil K test is most suitable for use on acidic soils which are naturally most prevalent across Ireland.

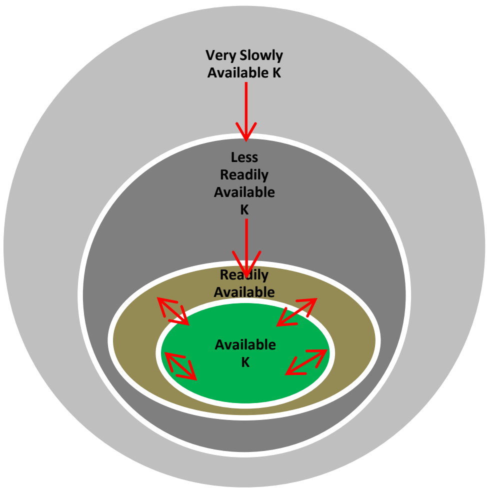

Figure 1. Different soil potassium pools and potassium movement between pools.

Soil test potassium

The soil test is a very reliable measure of plant available soil K during the growing season. In Ireland the Morgan's soil K extraction method has been shown to be well correlated to plant growth. The soil K index system is shown in table 1 for mineral and peat soils. For peat soils soil test K levels are higher as peat soils do not contain any clay minerals so they do not store and their K supply can be low. The Morgan's K therefore relates more to the total K content for peat soils resulting in higher soil test K as shown in table 1.

Table. 1 Soil K index, response to fertilizers (Teagasc, 2016)

Soil Index	Response to Fertilisers	Soil test K (mg/l)	
		Mineral	Peat
1	Definite	0 – 50	0 – 100
2	Likely	51 – 101	101 – 75
3	Unlikely / Tenuous	101 – 150	176 – 250
4	None	> 151	> 250

The optimum soil K index on mineral soils is Index 3. This is the desired soil index to maximise production for agricultural field crops.

Potassium function in plants & crop K deficiencies

Potassium is extremely mobile in plants and plays a key role in plant functions such as the opening and closing of plant stomata in the leaves, the uptake of water by root cells, plant osmotic potential and turgor of the guard cells and transport of photosynthate from the leaves.

Disease control

Potassium increases a plants tolerance / resistance to diseases in cereals such as powdery mildew. This has been observed in many trials conducted in both winter and spring barley in Ireland (Picture 1).

Picture 1. Powdery mildew on winter barley receiving a zero application of K (Arklow, 2016).

Potassium reduces straw-brackling & lodging in cereal crops

As reported previously K is a plant building lock and is very important in plant cell wall development. Cereal trials demonstrated the important role of K in helping to prevent both lodging and brackling in cereal crops. Picture2 shows a crop of winter barley with brackling and its impact on straw quality.

Picture 2. Potassium plays a key role in reducing plant lodging and brackling in cereal crops.

Plant analysis for potassium

Plant analysis is a useful tool to identify plant K sufficiency / deficiency during the growing season. As plants develop the uptake of K increases and plant K concentrations will decline due to K dilution. Once cereal plants reach maturity at harvest time there tends to be approximately 50:50 split of K between grain and straw. While for beans there tends to be a 60:40 split between seed and shoot K concentrations. Table 2 below shows typical K concentrations in plants.

Table 2. Plant K concentration (g/kg Dry Matter)

Element	Deficient	Low	Sufficient
K	<20	20 – 30	30 - 60
			Source: Teagasc Green Book, 2016

Where crops are harvested green such as grass silage / whole crop cereals significantly higher levels of K are removed at harvest time compared a crop of hay which tends to be cut later and more mature at harvest time similar to ripe cereal crops resulting in lower K off takes.

Potassium and nitrogen use efficiency

To maximise the efficient use and return from applied nitrogen it is important to maintain sufficient soil K levels and apply K regularly based on recent soil analysis to optimise grass production. Figure 3 shows the effect of increasing K fertilizer applications (zero to 240kg K/ha) on grass yield at two different rates of N (200 v 400kg N/ha) per year for a continuous cut grass silage sward at Johnstown Castle (2005 to 2009). Where the higher rate of N was applied it required higher application rates of K fertilizer (~200kg K/ha) to achieve maximum yield. This shows that when K applications are not matched to N fertilizer rates there is poorer utilisation of the N applied.

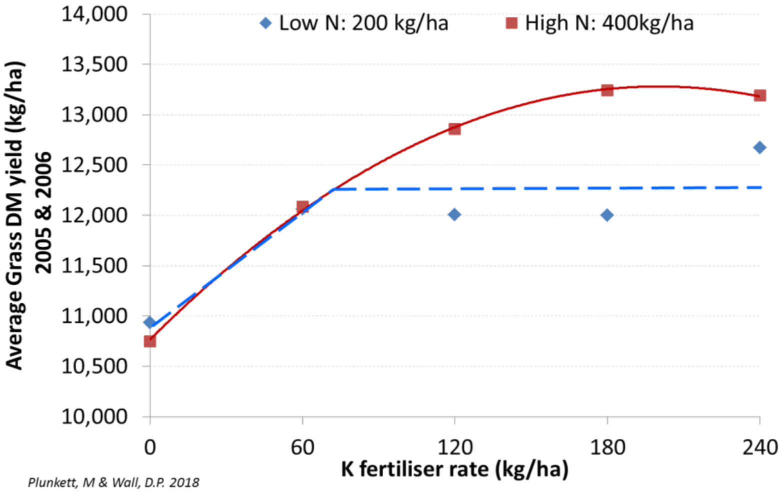

Figure 3. The effect of increasing potassium fertilizer applications on grass yield at two different N application rates (200 and 400 kg N/ha).

Potassium management and agronomic advice

The aim is to maintain soil K levels at Index 3 for optimum production. For grassland fertilizer K advice is based on soil analysis and whether the sward is been grazed or cut for silage. Crops such as cereals grain yields are taken into account plus the most recent soil analysis to determine crop K advice.

Potassium advice for grassland

The K requirements for grazing are relatively low as the majority of K is recycled by the grazing animals in dung and urine. For grass silage there can be large K off takes depending on grass silage yields and the number of grass cuts annually.

Maintenance K advice for grassland

Nutrient K advice at index 3 is to replace K removed in meat and milk. The K fertilizer K maintenance requirements are shown in table 3.

Table 3. Grazing maintenance rates of available soil K to replace offtakes (kg/ha)

Grassland Stocking Rate (kg/ha) Org N	Farming System	
	Dairy	Drystock
≤100	20	5
130	25	10
170	30	15
210	35	20
≥210	40	25

Soil K build-up advice for grassland

To build soil K levels to the optimum index 3 additional levels of K needed to be applied for a number of years. Soil K build-up rates are shown in table 4. It is recommended to apply build up rates of K in the autumn to reduce the risk of grass tetany in bovines. Whereas in K fixing soils (e.g. Athy Series) K should be little and often throughout the year.

Table 4. Available K rates (kg/ha) for build-up on mineral soils

Soil K Index	K Rates (kg/ha)
1	60
2	30
3	0
4	0

Potassium for Silage and Hay

Potassium requirements for silage and hay are large due to high K off-takes in harvested grass. Each 1 tonne of grass dry matter removes 25kg K/tonne. Table 6 shows the K fertilizer advice for silage and hay for 1^{st} & 2^{nd} cuts based on a grass yield of 5 and 3t/ha, respectively. It is important to remember that there is a K fertilizer requirement is for each cut. The K fertilizer requirement can be reduced by substituting some or all of the K fertilizer with organic manures.

Table 6. Potassium advice for 1st and 2nd cut grass silage (kg/ha)[1]

Soil Index	1st Cut / hay(5t DM/ha)	2nd Cut(3t DM/ha)[2]
1	185[3]	75
2	155[3]	75
3	125[3]	75
4	0	0[4]

[1]Increase K by 25kg/ha for each extra t/ha of dry matter

[2]Where K build-up has already been applied for the previous grass silage crop (i.e.1st cut) apply K based on crop off takes.

[3] Apply no more than 90kg/ha K at closing for silage and apply the remainder at least 3 months in advance or after silage harvest.

[4] In the year of sampling omit K and revert to Index 3 advice until new soil test.

Potassium advice for cereal crops

Cereal nutrient advice for K is based on maintaining the soil test at the agronomic optimum level of index 3. Potassium advice is determined by soil analysis and the expected grain yield for the crop. Where soil test results are below index 3 additional K will be required for a number of years to build soil K levels (see table 9). Fertilizer K advice takes crop yield into account since 2008.

Replacing K off-take

Table 6 shows the amount (kg) of K removed per tonne of grain yield. For example a 10t/ha crop winter wheat removes 98kgK/ha (Grain & straw). Where straw is chopped and incorporated after harvest crop K off takes are reduced from 98kg K/ha to 47kg K/ha. There is approximately a 50:50 split of K between grain and straw in cereal crops. Where high yielding crops are harvested each year it is important to adjust the K advice to take account for higher K removals. This will help maintain soil K levels at the optimum soil K index 3.

Table 7. Potassium off-take in cereal crops (kg/ha) per ton of grain yield

Crop	Straw Removed	Straw Chopped
W.Wheat/ Barley	9.8	4.7
Sp. Wheat / Barley	11.4	4.7
Oats	14.4	4.7

Soil K build-up for cereals

Table 8 shows additional K required at soil index 1 and 2 to build soil K levels to the optimum soil Index 3. Building soil K will take a number of years depending on the soil type and the clay mineralogy. On sandy or organic soils, don't build soil K levels. Apply adequate K levels for yield on an annually e.g. index 3 advice as per table 9.

Table 8. Available K rates (kg/ha) for Build-Up on mineral soils

Soil K Index	K Rates (kg/ha)
1	30
2	15
3	0
4	0

Potassium advice for cereals crops

Table 9 shows the K advice for a range of cereal crops where straw is removed at harvest time.

Table 10. Potassium advice for cereal crops where straw is removed (kg/ha)[1]

Soil K Index	Winter Wheat[2]	Winter Barley[2] / Spring Wheat[3]	Spring barley[2]	Winter Oats[4]	Spring Oats[4]
1	140	130	115	160	140
2	115	115	100	145	125
3	110	100	85	130	110
4	0	0	0	0	0

[1]Assumed crop yields

Winter wheat – 11t/ha Spring wheat – 8.5t/ha

Winter barley – 10t/ha Spring barley – 7.5t/ha

Winter oats – 9.0t/ha   Spring oats – 7.5t/ha

[2]For winter wheat and winter barley crops increase / decrease K rate by 9.8 kg/ha per tonne increase / decrease in grain yield.

[3]For spring wheat and spring barley crops increase / decrease K rate by 11.4 kg/ha per tonne increase / decrease in grain yield.

[4]For spring oats and winter oats crops increase / decrease K rate by 14.4 kg/ha per tonne increase / decrease in grain yield.

Timing of potassium applications

Grassland

The fertilizer K application strategy should be carefully planned especially where high levels of K are required. For example in springtime K applications should not exceed 90 kg K/ha in a single application on silage fields. Where higher rates are required it is advised to split the application and apply the balance to the silage aftermath or in late autumn. For grazing ground apply maintenance rates of K in the spring and apply the balance in August / September. On fast growing swards which have received high levels of nitrogenous and potassic fertilizers grass tetany (grass staggers) can become more prevalent. High soil K levels can induce grass tetany as it antagonises magnesium uptake by the grass crop. In areas where the disease is known to be problematic it's advisable to feed cal-mag three weeks before and after susceptible periods.

Cereal Crops

For cereal crops the timing of application will depend on crop type for example winter or spring cropping. For winter cereals on very low to low K index soils it is recommended to apply a portion of the crops K requirements and incorporate at sowing time for exmple ~30% of recommended rate. The remaining crop K requirements can be top dressed in early spring to coinside with N, P, K & S applications. On Index 3 soils K can be applied at time during the growing season ideally with the 1st application of fertilisers in spring time. For spring crops it is recommended to apply all crop K requirements at sowing time and incorporate into the seedbed. On index 4 soils it is recommended to omit K applications for 1 year and revert back to K index 3 requirements until the next soil sample.

Other crops

For other crops such as root crops / peas / beans it is recommended to apply crop K requirements at sowing time and work into the seedbed before or during crop establishment.

References

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