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FERTILIZER ASSOCIATION OF IRELAND

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Cutting back on fertilizer for grassland in 2007

James Humphreys, Teagasc, Moorepark

New Regulations

Regulations stipulating the quantities of fertilizer N that can be applied to grassland have been implemented under Statutory Instruments (SI No. 378 of 2006) which came into effect in Ireland on 1 August 2006. Derogation from these SI has been granted until 17 July 2010 on Irish farms under certain circumstances. In terms of fertilizer N use for the foreseeable future (until July 2010) it seems that meeting the requirements of these new regulations does not pose a serious difficulty for the vast majority of Irish grassland farmers. The quantities of fertilizer N that can be applied within the three stocking rate categories and the closed periods for applications of fertilizers and slurry in different parts of the country are shown in Table 1.

Table 1. Permissible rates of fertilizer N for grassland and closed periods for fertilizer N and slurry application in different counties during 2007. Rates of fertilizer N are presented in kg per ha (units per acre in brackets)

Stocking rate (kg per ha of organic N)	Carlow Cork Dublin Kildare Kilkenny Laois Offaly Tipperary Waterford Wexford Wicklow	Clare Galway Kerry Limerick Longford Louth Mayo Meath Roscommon Sligo Westmeath	Donegal Leitrim	Cavan Monaghan
	Fertilizer N kg/ha (units/acre)			
≤ 170	210 (170)	208 (169)	206 (167)	204 (166)
171 – 210	287 (232)	284 (230)	282 (228)	279 (226)
211 – 250	256 (207)	253 (205)	250 (203)	247 (200)
	Closed periods			
Fertilizer	15 Sept–12 Jan	15 Sept–15 Jan	15 Sept–31 Jan	15 Sept–31 Jan
Slurry	15 Oct–12 Jan	15 Oct–15 Jan	15 Oct–31 Jan	15 Oct–31 Jan

**Applying fertilizer N up to these limits on many farms may not be good agronomic practice and may be a waste of money. In many situations less fertilizer N is needed to meet sward requirements. See Tables 4 and 5 below.*

Rising costs

The manufacture of nitrogenous fertilizers is an energy-demanding processes and the cost of fertilizer N is closely linked to the cost of energy on the world market (Figure 1). Over the last decade there has been a steady rise in the cost of energy and this upward trend seems set to continue. During this period the cost of fertilizer N has increased by approximately 60% (Figure 1). Concurrently, there has been a steady decline in the farm-gate price received for milk being only 90% of that in 1998 (Figure 1). The overall impact of these changes has been a doubling of the cost of fertilizer N relative to milk price during the last decade. In other words, during 2006 on a typical dairy farm in Ireland it was necessary to sell three litres of milk to purchase one kilogram of fertilizer N, whereas the same quantity of fertilizer N could be purchased by the sale of one and a half litres of milk a decade ago.

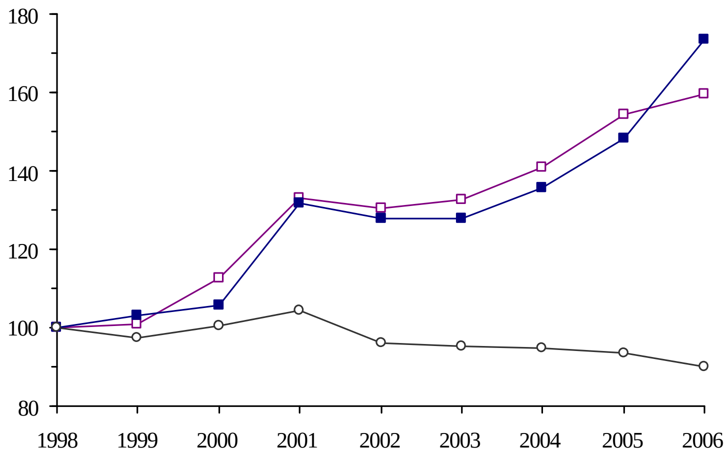

Figure 1. The unit cost of energy (■), fertilizer N (□) and milk (○) relative to 1998 baseline.

This price:cost squeeze has contributed to a decrease of 21% in the average amount of fertilizer N being used on Irish farms since 1998 (Figure 2). Nevertheless, this decrease has not been sufficient to offset rising costs and, while fertilizer N use has fallen, average expenditure on fertilizer N on Irish farms has risen by 27% (Figure 2). The competitiveness of Irish dairy production in a European context is largely based on our capacity to grow and efficiently utilize large quantities of low-cost grazed grass over a long grazing season. The production of large quantities of pasture per hectare is predominantly determined by input of fertilizer N. The rising cost of fertilizer N is contributing to the erosion of the profitability of Irish grass-based systems of production.

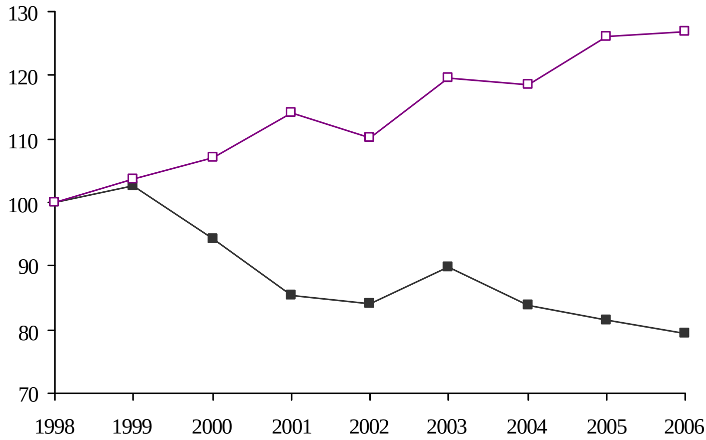

Figure 2. The annual quantity of fertilizer N used (■) and annual expenditure on fertilizer N (□) on Irish farms relative to 1998 baseline.

Rising costs and statutory limits are focusing attention on fertilizer N use on farms. Improvements in fertilizer N use efficiency can be achieved by attention to detail when it comes to applying fertilizer N, making use of slurry to replace fertilizer N and by making more use of white clover in swards.

Fertilizer N use on Intensive dairy farms

Surveys of fertilizer N use on intensive dairy farms indicate that there is considerable variation in quantities of fertilizer N used on farms with similar stocking rates (Figure 3). There are a number of reasons for this including differences in soil-type and natural background fertility (see below). There are also differences in the type of stock being carried and in the extent to which maize and other forage crops are grown on farms and the extent to which concentrates and other feeds are imported onto farms. These latter aspects will tend to lower fertilizer N use on farms. Nevertheless it is also clear that some farmers are using N more efficiently on their farms compared to others. It can be seen in figure 3 that fertilizer N use on farms stocked at 2.5 LU/ha ranges between around 225 and 400 kg/ha. This raises the question of why one farmer is able to get away with using much less fertilizer N than the other?

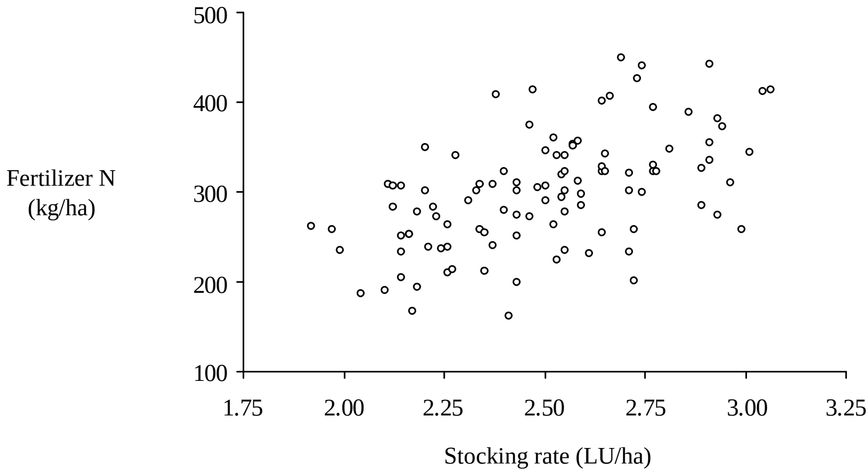

Fig 3. Fertilizer N use on intensive dairy farmers in the south west of Ireland.

Factors influencing losses of nutrients from the soil

Available N for uptake by the sward

Efficient management of N on farms requires that N is supplied to the soil at a time and in a manner that ensures that as much of that N as possible is taken up by the sward and used to grow grass to feed livestock. This requires that losses between application to the soil and uptake by the sward are minimised. An understanding of the factors that can cause losses of N from the soil can help to improve the management and use-efficiency of fertilizer N.

Nitrogen is available in the soil to plant roots in two forms: nitrate and ammonium. Both of these can be taken up and used by the sward; it makes little difference to the sward. Fertilizers supply both nitrate and ammonium, for example, CAN is calcium ammonium nitrate. Urea, on the other hand, is broken down to ammonium once it is applied to the soil. Any ammonium that is not readily taken up by the grass roots accumulates in the soil where it is converted to nitrate. This is unfortunate because nitrate is very prone to being lost from the soil.

Soil particles are negatively charged. Ammonium in the soil is positively charged and therefore ammonium is held quite well in the soil. In contrast, nitrate is negatively charged and therefore is not held very well in the soil (it is repelled from soil particles in the same ways as similarly charged magnets repel each other). Therefore nitrate in the soil moves very easily with movements of the soil water. This facilitates transport of nitrate to the plant roots when soil water is being taken up by the sward. The soil water is drawn to the plant roots by a process called evapotranspiration. Evapotranspiration is the combined effects of evaporation and transpiration, which draws water out of the soil and up into the grass roots. Around 450 mm of water is drawn out of the ground by evapotranspiration each year and goes off into the atmosphere as water vapour. This is the equivalent of 4,500 cubic metres of water per hectare each year (a little less than 400,000 gals/acre).

Nitrate leaching and denitrification

The mobility of nitrate is a disadvantage under conditions of high rainfall because it leads to leaching. This is a mechanism by which nitrate is washed out of the topsoil as the water passes down through the soil profile. Leaching of nitrate is mostly associated with sandy free-draining soils where surplus rainfall is readily washed down through the soil profile. In heavy soils with impeded drainage, nitrate is lost by a different mechanism that is also dependant on the soil water status. Under high rainfall the soil pores of heavier soils get increasingly saturated with water. This drives oxygen out of the soil. Under such circumstances certain bacteria in the soil are able to take the nitrate (NO_3) and detach the oxygen (O_2) and use it to survive the waterlogged conditions. This process is called denitrification and leads to the release of N_2O and N_2 gasses into the atmosphere. Denitrification is by far the most important mechanism for loss of N from Irish farms.

Therefore leaching of nitrate and denitrification of nitrate are caused by wet soil conditions usually due to high levels of rainfall. In Ireland, there are high rates of rainfall during the autumn, winter and spring (Figure 4). In contrast, there are highest rates of evapotranspiration during the late spring, summer and early autumn (Figure 4).

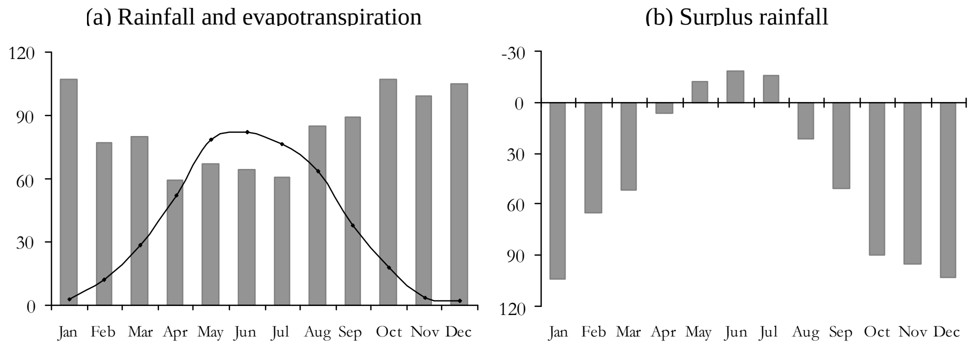

Figure 4. (a) Average monthly rainfall (bars) and potential evapotranspiration (lines) (mm/month) and (b) Surplus rainfall (mm/month)

Average rainfall in Ireland is around 1000 mm per year, whereas evapotranspiration is around 450 mm per year. The difference is known as surplus rainfall, which either drains down through the soil or runs off the soil surface into drains etc. This surplus rainfall amounts to around 550 mm per year (5,500 cubic metres of water per hectare or around 500,000 gals/acre).

It can be seen in figure 4(b) that most of this surplus rainfall occurs between October and January. These huge volumes of surplus rainfall can cause considerable losses of nutrients either by denitrification of nitrate, nitrate leaching and losses of P and K from the soil. This has implications for the timing of application of fertilisers and slurry.

Volatilisation of Ammonia

These opposing effects of rainfall and evapotranspiration also influence the other important mechanism of N loss from grassland, which is the volatilisation of ammonium (NH_4) to ammonia (NH_3) gas. This loss of N is generally associated with the application of urea fertilizer. Once urea is applied to the soil, it is broken down into ammonium dissolved in the soil water. Ideally this soil water seeps down to the grass roots. However, under drying weather conditions, the water containing the ammonium can be evaporated off into the air as water vapour. The ammonium dissolved in this water is like-wise volatilised off as ammonia gas. It can be seen in figure 4(b) that evapotranspiration exceeds rainfall during May, June and July. Hence, these are the months when there is greatest risk of volatilisation. Generally speaking, it is not recommended that urea fertilizer be used after the beginning of May for this reason.

While volatilisation is mostly associated with urea fertilizer in many people’s minds, the greatest losses of N by volatilisation occur during the application of slurry. The N in slurry is in two main forms: (1) ammonium and (2) organic material, which is the solid fraction of the slurry, such as the fibrous residue of digested silage etc. Ammonium accounts for around 50% of the N in slurry and the solid fraction accounts for the other 50%. Once the slurry is applied the ammonium is immediately available for uptake by the sward. The N in the solid material only becomes available as the organic material rots away over time.

However, the ammonium in slurry can easily be lost by volatilisation in the same way as it is lost following the application of urea fertilizer. In fact, virtually all of the ammonium in slurry applied between May and August can be lost by volatilisation, particularly where slurry is applied to bare silage stubble under dry conditions during the summer. This is partly because of the weather conditions but it is also due to the method of application. The application by splash-plate where the slurry is sprayed into the air promotes the process of volatilisation. These losses occur during and immediately after application and virtually all of the ammonium in the slurry can be lost within a few hours of the slurry being applied. This loss mechanism occurs very quickly and results in large losses of N. The application of 33 cubic metres/ha (3000 gals/acre) of slurry can contain around 100 kg N/ha, half of which is ammonium dissolved in the liquid fraction. Hence, around 50 kg N/ha is rapidly lost by volatilisation when the slurry is applied under the wrong conditions. This is a lot of N when it is considered that average fertilizer use by the group of intensive dairy farms presented in figure 3 is 300 kg fertilizer N/ha. In other words the above 50 kg ammonium-N in slurry represents one-sixth of fertilizer N use on these farms. This indicates one area where there is scope to improve efficiency.

Volatilisation losses can be minimised by applying slurry under conditions that promote the rapid infiltration of the slurry into the soil. Two factors facilitate the achievement of this objective (1) applying slurry under damp misty conditions and (2) applying fairly dilute slurry.

Damp conditions

To get best response to slurry, it is necessary to apply slurry under cool damp misty conditions and that these conditions precede or coincide with active grass growth and rapid uptake of nutrients from the soil. The most ideal concurrence of these conditions is during the spring during the months of February, March and April. These conditions coincide also during September and October. However, when slurry is applied in October, this slurry is being applied just prior to the four wettest months of the year (Figure 4a) and at a time of declining grass growth during which the uptake of nutrients is also in decline. Hence, while applying slurry in October might lower ammonia losses, the risk of losses of P in runoff and of losses of nitrate by denitrification and leaching over the winter is substantially higher. Hence, for autumn applications of slurry, it is best that slurry is applied during late August and September.

Greatest responses can be achieved with slurry applied during the spring. This is because the slurry is being applied at a time that promotes the infiltration of the slurry into the soil. There is also a huge increase in grass growth going from around 5 kg DM/ha/day in January to around 80 kg DM/ha/day by the end of April. This generates a huge demand for the nutrients ensuring rapid uptake and efficient utilization of the nutrients in the slurry. Furthermore, it was pointed out above that around half of the N (and a substantial proportion of the P) in slurry is contained in the solid material. When slurry is applied during the spring, the solid material gets washed down into the soil where it rots away slowly during the summer months. Therefore the nutrients released by the rotting of the solid material are available for uptake by the sward during the summer months. In contrast, when slurry is applied during October, the solid fraction rots away during the winter months, when uptake by the sward is low and there is high rainfall causing the loss of these newly released nutrients by run-off, denitrification or leaching. Therefore, the spring is the best time to apply slurry followed by the early autumn (late August and September).

Application of Dilute Slurry

The solid fraction or DM of slurry in Ireland generally accounts for between 2% and 10% of the total volume of slurry. As slurry becomes more dilute due to rainwater or mixture with dirty water, this causes a dilution of the nutrients contained in the slurry. It also creates greater volumes of slurry that need to be managed.

One surprising aspect of the efficiency of utilization of N in slurry is that as slurry gets more dilute, the relative efficiency of utilization of the ammonium-N increases. This is because dilute slurry infiltrates into the soil much more quickly than higher DM slurry. With high DM slurry, the slurry is more likely to adhere to grass where it remains exposed to the air. This exposure leads to volatilisation. The dilute slurry dribbles down into the soil. The ammonium adheres to soil particles where it is available for uptake by the grass roots.

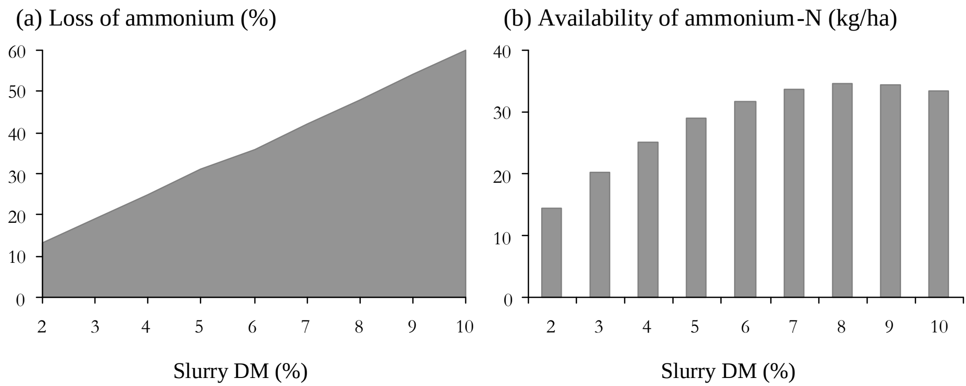

Figure 5. The effect of slurry dry matter content on (a) loss of ammonium following application expressed as a percentage of the ammonium present in the slurry prior to application (*from* Pain, 2000) and (b) availability (kg/ha) of ammonium-N in the soil for plant uptake following application of 33 cubic metres slurry/ha (3000 gals/acre).

In figure 5(a) it can be seen that as the DM content of the slurry increases, the proportion of the ammonium-N that is likely to be lost also increases. In other words, as slurry becomes more dilute, the ammonium-N in the slurry becomes less concentrated, but as it does, the ammonium-N is less likely to be lost by volatilisation following application. The net effect is that as the DM of the slurry decreases from 10% to 6% the availability of the ammonium-N for uptake by the sward remains more-or-less the same in terms of kg N/ha for the same volume of slurry applied (Figure 5b). With more dilute slurry (less than 6%DM) the availability of ammonium-N decreases but not at a rate directly proportional to the extent of dilution.

Increasing the dilution of slurry increases the volume of slurry that needs to be handled and this is a disadvantage. On the other hand, making the slurry more dilute increases the efficiency of N utilization. This is particularly the case for slurry applied during the summer months when the likelihood of volatilisation is greatest. Hence, greater dilution may not necessarily be wholly disadvantageous. Dilution should only be carried out where it is a convenient means of managing dirty water and at times of the year outside of the closed period for slurry application (Table 1).

Grass growth and nutrient uptake from the soil

High efficiency of nutrient-use on a grassland farm requires the efficient transfer of the nutrients available in the soil into the grass sward. The longer that nutrients are available in the soil and not taken up by the sward the longer they are at risk of being lost. The efficiency of transfer of available nutrients from the soil into the grass sward depends to a large degree on the rate of grass growth. For example, during good grass-growing conditions the sward takes up large amounts of available soil nutrients each day. During conditions of poor growth during the winter or during drought conditions, the uptake of nutrients can be virtually zero. Therefore grass growth, and the factors that influence grass growth, have a major bearing on the efficiency of nutrient-use on grassland farms.

Factors influencing grass growth

Solar radiation (day length and intensity), soil temperature and soil moisture are the three primary determinants of grass growth. Solar radiation provides the energy that fuels grass growth through the process of photosynthesis. The extent of solar radiation depends on the combination of day length and the intensity of the solar radiation (Figure 6a). Day length varies from around 8 hours/day in mid-winter and 16 hours/day in mid-summer. However, as can be seen from figure 6(a), the incidence of solar radiation is about 10-times higher in mid-summer than in mid-winter. This is because the intensity of solar radiation is about 5-times higher in mid-summer than in mid-winter. This is fairly obvious when you think about it; the risk of sunburn is much higher in summer than in winter.

During the winter and early spring low soil temperatures limit grass growth. At soil temperatures of less than 4.5°C there is no net accumulation of new pasture. Between 4.5°C and 6.0°C there are small amounts of pasture accumulation. It is only when soil temperatures increase above 6.0°C that there are substantial amounts of grass growth. Grass growth increases rapidly with increasing soil temperatures above 6.0°C. It can be seen in figure 6(d) that there is considerable variation in soil temperatures between Valentia in the southwest and Clones in the northeast. Grass growth continues virtually all the year round at Valentia but is limited by low soil temperatures during December, January and February at Clones.

Soil temperatures are often considered to delimit the length of the grass-growing season. However, solar radiation has a much greater influence on the extent of the grass-growing season in Ireland, as can be seen by comparing figure 6(a) and figure 6(c). This is hardly surprising taking into account that solar radiation is the fuel that drives grass growth. The most conspicuous difference between solar radiation and grass growth is the peak of grass growth that occurs during May that is not reciprocated in the incidence of solar radiation. This peak of grass growth is generated by changes in the internal physiology of the grass sward. During April many of the tillers in a grass sward become reproductive; i.e. they begin gearing themselves up to start producing seeds. These tillers shut off translocation of nutrients to the roots, production of daughter-tillers etc. and concentrate translocation of all available nutrients towards seed-head production, which causes the peak of DM production during late May. This can generally be observed as the sward becoming stemmy during May. Once these reproductive tillers are killed off by grazing or topping, they are replaced by vegetative tillers leading to an increasingly leafy sward from mid-summer onwards. These vegetative tillers are not as highly productive as the reproductive tillers. During the second half of the year the sward is focused on producing new daughter-tillers and on the accumulation of a reserve of sugars in the stubble that is used to sustain the grass over the winter months and to fuel initial growth during the following spring.

When soil temperatures (Figure 6d) are compared to grass growth (Figure 6c) it can be seen that while grass growth increases very rapidly during March and April to reach the peak in late May, soil temperatures are much slower to increase during this period. This is because soil temperatures are influenced by solar radiation. During the winter the soil cools down as day length and solar radiation intensity decline. From mid-winter onwards, days get progressively longer and solar radiation increases in intensity. However, it takes a while for the soil to heat up and therefore there is a lag between the incidence of the solar radiation (Figure 6a) and the consequent increase in soil temperature (Figure 6d). Whereas highest solar radiation occurs during May, June and July, highest soil temperatures do not occur until June, July and August because of this lag. On the other hand, as the incidence of solar radiation declines from mid-summer onwards, soil temperatures are much slower to cool down. While lowest solar radiation coincides with the shortest days in late December, lowest soil temperatures are recorded during January and February. Early February is often the coldest time of the year.

This has clear implications for grass growth. Soil temperatures generally place a greater constraint on grass growth during the spring than during the autumn. During the autumn grass growth is constrained more by decreasing solar radiation and by changes in the physiology of the sward. During the late autumn the sward begins to accumulate resources in the stubble rather than producing new leaves that might be burned off by frost. Also, the grass leaves are the machinery that absorbs solar radiation for photosynthesis. The cost of running this machinery is respiration, which describes the energy used to maintain the internal workings of the grass sward. As solar radiation declines during the autumn the respiration cost associated with a large amount of leaf material can begin to exceed the level of photosynthesis that can be generated using the declining solar radiation. Hence, having a large amount of leaf material starts to become a liability. Under such circumstances there can be net respiration where the sward is burning more energy than is being absorbed from solar radiation. Under such circumstances the grass starts to shed some of its leaf material, which is often manifested as white-tips on the leaves of grass. In the past, the white tips on heavy covers of grass during the late autumn have occasionally been attributed to N deficiency. This is an erroneous assumption. This process can also lead to a loss of DM when heavy covers are carried into the winter.

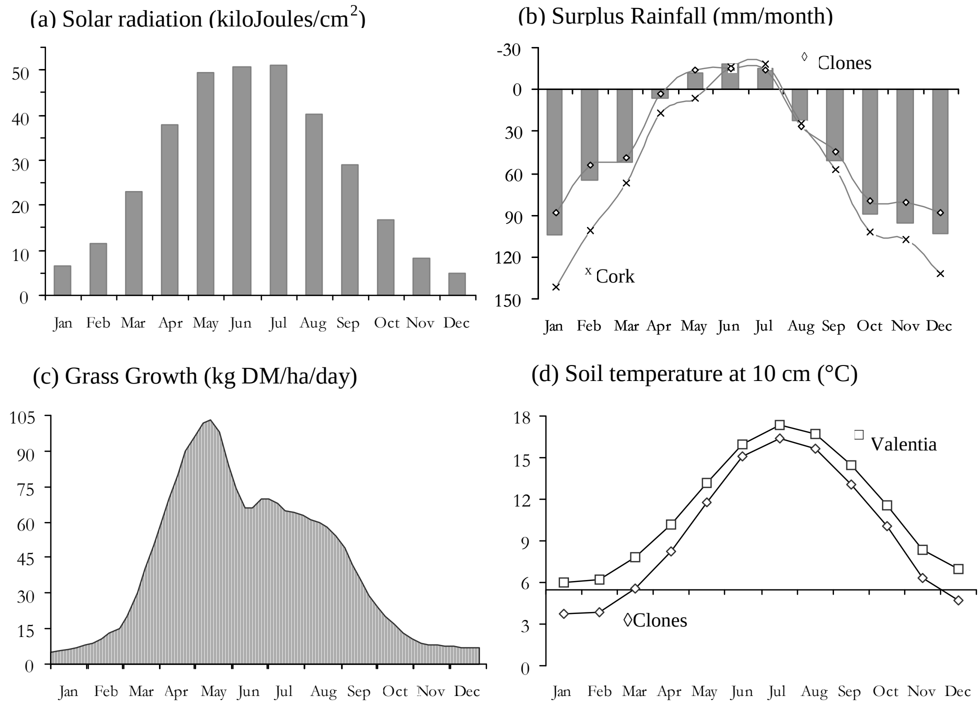

Figure 6. Global solar radiation, surplus rainfall, grass growth and soil temperatures during the year

It has been pointed out above that a soil temperature of 6.0°C is seen as an important threshold for grass growth during the spring. It has occasionally been suggested that, because soil temperatures remain above 6.0°C until as late as November, this justifies the application of fertilizer N during November. This is nonsense. Applying fertilizer N during November is a complete waste of money. The possibility of getting any worthwhile response in grass growth to fertilizer N is long gone by November. Furthermore, as can be seen from figure 6(b), high rates of surplus rainfall will be entering the soil during November, December and January during a period when uptake by the sward will be virtually zero. Fertilizer N will not remain for long in the soil under such conditions.

Generally speaking, soil temperatures during the winter and spring are relatively high in coastal areas in the south and west compared with inland areas of the north and east (Figure 6d). This has implications for the application of fertilizer N during the spring. In contrast to soil temperatures, the incidence of solar radiation varies relatively little in different parts of the country. Therefore, while higher soil temperatures during the winter favour a longer grass-growing season in the southwest, there can be much less of a difference in the amount of grass grown during the year. It can be seen in Table 2 that there is little difference in the amount of grass grown in Moorepark, Co. Cork compared to Ballyhaise, Co. Cavan, although Ballyhaise is much further to the north. The implication is that at colder locations, there is much the same potential to grow grass except that it will be grown over a shorter growing season usually characterised by a huge surge in grass growth during April and May.

Table 2.The productivity of permanent grassland under simulated grazing around Ireland (*based on at least 6 years of measurement*)

Site	Production (t DM/ha/yr)	SD
Moorepark, Co. Cork	14.5	1.2
Kilmaley, Co. Clare	14.2	1.8
Solohead, Co. Tipperary	15.8	1.9
Ballyhaise, Co. Cavan	14.4	1.5
Grange, Co. Meath	13.6	1.0

In contrast to annual rainfall, which generally ranges between 1400mm in the south and west and less than 800mm in parts of the east, evapotranspiration varies very little from place to place. This is because evapotranspiration is caused by solar radiation. The close relationship between the two can be seen by comparing figure 6(a) and figure 6(b). There are clear relationships between the factors that influence grass growth and hence requirements for nutrients from the soil and the factors that are likely to lead losses from the soil. During the main growing season there is huge demand for N from the soil whereas the risk of loss is limited to volatilisation of ammonia. During the winter the demand for N is low whereas the risks of denitrification and leaching are high. The important questions are (1) when to start applying fertilizer N in the late winter or spring and how much to apply? And (2) when to stop applying fertilizer N during the autumn?

Fertilizer N recommendations for grassland

The requirement for available soil N

It can be seen in Table 2 that annual grass production rarely exceeds 15 t DM/ha. The growth of 15 t of grass DM requires the uptake of at least 450 kg N/ha from the soil. Nitrogen is a key component of chlorophyll, which is where photosynthesis takes place. The uptake of at least 450 kg N/ha from the soil supplies 30 g/kg N in the grass DM, which is the minimum required for optimum photosynthesis. However, it is not necessary to supply all of this as fertilizer N. This is because soils have the capacity to supply a certain amount of N, known as background N, each year (Figure 7a).

Background availability of N in the soil

Mineral soils (as opposed to peat soils) in Ireland contain around 8.5% organic matter (ranging between 5 and 20%) mixed in with the sand, silt and clay particles. This organic matter has accumulated in the soil over thousands of years. It is made up of decaying grass, roots and other herbage, the organic material deposited in dung and slurry etc. It is a very important component of the soil. It is the glue that holds soil together. It plays an important role in water retention and availability. It is also an important component of soil fertility, regulating the availability of many nutrients in the soil. The soil organic matter (SOM) contains around 7,000 kg of N/ha. Most (98%) of this N (SOM-N) is in a form that is not available for plant uptake. However, the SOM is constantly being turned over by earthworms and other soil organisms and this turnover makes a small amount of this N available for uptake by the sward each year (Table 3).

The background availability of N from Irish grassland soils is around 140 kg N/ha/year ranging between 74 kg/ha and 212 kg/ha (Table 3). These results indicate the range in background availability of N that can be expected from Irish grassland soils. Lower quantities are associated with soils with shallow topsoil and with lighter soils. Higher quantities are associated with heavier soils and soils with deeper topsoil. Soil organic matter content and drainage status are also important characteristics.

There is a wide range in the amount of fertilizer N being used on intensive dairy farms (ranging between 225 and 400 kg N/ha for farms stocked at 2.5 LSU/ha; Figure 3). It is fairly obvious that a large part of this difference is due to the difference in background release of N on different farms. On otherwise fertile sites, there can be a difference of 100 kg N/ha in background availability of N during the growing season (for example, Clonroche and Johnstown Castle, both in Co. Wexford). This clearly has implications for fertilizer recommendations and for the requirement of fertilizer N on farms.

Table 3. Background availability of N from grassland soils in Ireland (*K. O'Connell, unpublished data*)

Location	Background availability (kg N/ha/year)		Background availability (kg N/ha/year)
Ballinamore	74	Clonakilty	141
Kilmaley	79	Solohead	142
Clonroche	102	Tullamore	156
Oakpark	112	Grange	190
Kildalton	113	Ballyhaise	158
Gurteen	122	Johnstown Castle	203
Moorepark	130	Pallaskenry	212
Athenry	140	Average	139

The requirement for fertilizer N during the spring

The release of background N continues right throughout the year. The rate of availability is influenced by soil temperature and moisture status. Highest rates of availability are associated with the high soil temperatures during August and September once there is plenty of water available in the soil; availability is impeded by drought conditions. Lowest rates of availability occur during the winter due to cold soil conditions and waterlogging. Nevertheless, substantial quantities of background N can be made available during the winter. For example, between late October and the middle of March the background release of 43 kg N/ha has been recorded at Moorepark (O'Donovan *et al.*, 2004). This is the equivalent of 270 g N/ha/day. Estimates of N release during the winter at Solohead and Moorepark generally range between 200 and 250 g N/ha/day during November, December and January.

In figure 7(a), the background availability of N based on data from Solohead and Moorepark is presented in comparison with the requirement for 450 kg fertilizer N/ha by a sward producing 15 t DM/ha/year (close to maximum potential production). It can be seen that the background release of N is able to meet the requirements of the sward during November, December and January. The release of between 200 and 250 g N/ha/day during this period is sufficient to support growth of between 600 and 700 kg grass DM/ha, or a growth rate of around 7.0 kg DM/ha/day.

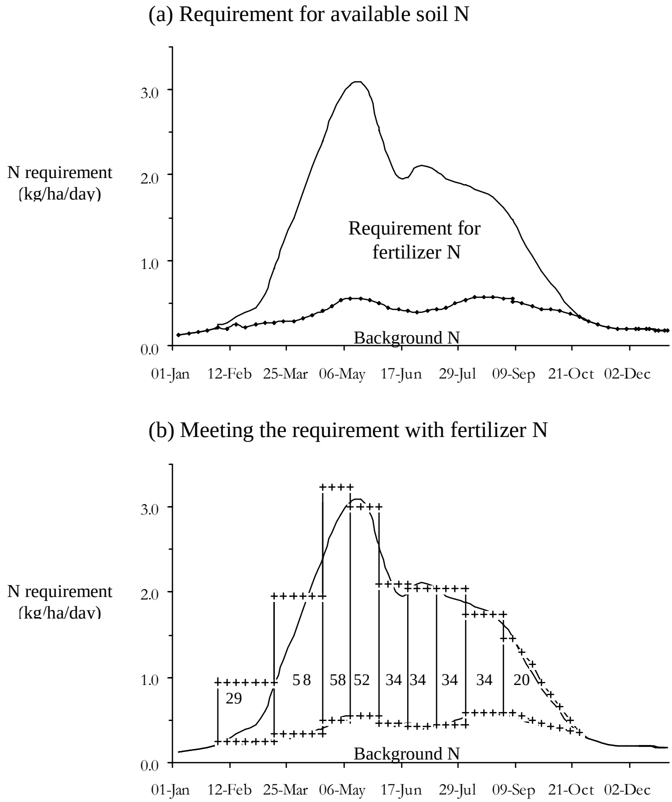

Figure 7. The annual requirement for available soil N by a sward producing 15 t DM/ha/year, and meeting that requirement from background availability of N in the soil and applied fertilizer N

At some stage during January and February the demand of the sward for available N from the soil begins to exceed the background supply. At this point there is likely to be a response to fertilizer N. As can be seen from soil temperatures (Figure 6d; Figure 8), this can be as early as mid-January in the southwest and as late as mid-March in the north. Over large parts of the country the point where requirement for fertilizer N begins to exceed background supply is likely to be in mid-February.

The next question that arises is how much fertilizer N to apply during the early spring? At Moorepark, O'Donovan *et al* (2004) showed very high production responses in terms of grass grown by 18 March to fertilizer N input of 90 kg N/ha. For experimental reasons all of this fertilizer was applied in one application. When this fertilizer was applied between mid January and early February, recovery in the sward was around 50%. Earlier application resulted in lower rates of recovery. It is fairly obvious that the reason for this relatively poor rate of recovery was due to the high levels of surplus rain (Figure 6b) coinciding with low rates of N uptake from the soil (Figure 7). In other words around 45 kg N/ha is being lost before it ever contributed to grass production. While some losses are unavoidable, splitting the application; i.e. 30 kg/ha applied in mid-January and the remaining 60 kg/ha is applied in mid-February, will lower the risk of loss because the bulk of the fertilizer is applied closer to the time of high uptake by the sward. This will vary with location. Therefore, it is generally recommended that 29 kg N/ha (23 units/acre) is applied in the first application and that this is followed four to six weeks later by around 58 kg/ha (46 units/acre) depending on growing conditions (Figure 7b). The initial application may need to be as early as mid-January in the southwest, mid-February in the midlands and the end of February in the northeast. This strategy will result in higher recovery of N by the sward resulting in more efficient use of N on the farm.

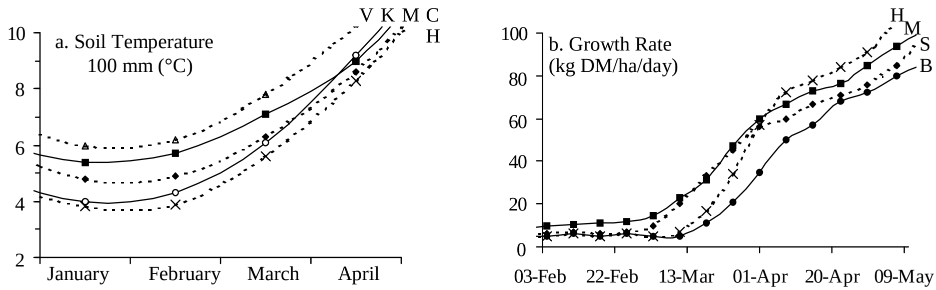

Figure 8. (a) Soil temperatures during the late-winter and spring at a range of sites in Ireland from the south west to north (V = Valencia ∆; C = Cork airport ♦; M = Moorepark ■; K = Kilkenny ° & H = Clones ×) and (b) grass growth rates during the spring at a range of sites in Ireland from south to north: (M = Moorepark ■; S = Solohead ♦; H = Ballyhaise × & B = Ballinamore •).

In figure 7(b) a fertilizer N application strategy to meet the demand for fertilizer N is outlined. This is based on a fairly typical approach for intensive dairy farms where half bag of urea/acre is applied in February followed by a bag of urea/acre during March and again during April. This is followed by a bag and a half of CAN/acre during early May, and a bag of CAN/acre at around four-week intervals during late May, June, July and August. A bag or half a bag CAN/acre is applied during early to mid-September. The total quantity of fertilizer N applied is around 350 kg N/ha. O'Connell *et al.*, (2004) tested a similar application strategy where fertilizer N was applied at three-week intervals at Solohead and Moorepark. Recovery of fertilizer N was as low as 25% during February increasing to around 75% during May. Low rates of recovery of fertilizer N were attributed to the high rates of surplus rainfall during this period. From late May until late August, rates of recovery approached 100%. This result can also be attributed to the balance between rainfall and evapotranspiration. During the summer evapotranspiration exceeds rainfall and the soil remains relatively dry. There is little risk of losses due to denitrification. Furthermore, the soil water is held in the topsoil and there is virtually no risk of leaching. Nitrate dissolved in the soil water is retained in the topsoil. From early September onwards the rate of recovery begins to decline in line with declining grass growth and with increasing quantities of surplus rainfall entering the soil. Over the whole growing season, the recovery of fertilizer N was a little over 80%. The greatest losses of fertilizer N occurred during the springtime.

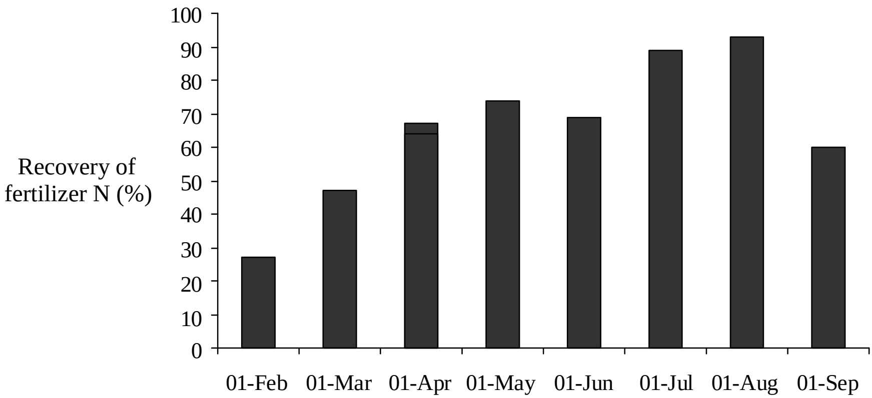

Figure 9. Recovery of fertilizer N (%) during the grazing season (O'Connell, 2005)

Strategies to lower fertilizer N requirements on farms

Matching fertilizer N use to stocking rate

Recent work at Solohead has shown that, with grass-only swards, around 170 kg fertilizer N/ha is required to support a stocking rate of around 2.0 LSU/ha. Average fertilizer N use on Irish dairy farms stocked at 2.0 LSU/ha is 175 kg/ha (Coulter *et al.*, 2002). Therefore there is good conformity between the rate of fertilizer N being used on farms, generally, and that found to be necessary to support this stocking rate at Solohead. Furthermore, at Solohead, it was found that for every increase in stocking rate by 0.1 LSU/ha, an additional 30 kg N/ha was required (Humphreys *et al.*, 2004). Under typical grassland management where most of the silage is made as first-cut and the amount of second-cut is kept to a minimum (between 0 and 30% of the grassland area), the fertilizer N application strategies presented in Table 4 are recommended. These recommendations adhere to best agronomic practice while complying with the new regulations.

Best response to fertilizer N will be achieved by applications made during late March, April and May. During this time of the year, it pays to put on high rates of fertilizer N on the grazing area, maximise the stocking rates on the grazing area and make as much ground as possible available for first cut silage. Because of the high rates of grass growth during late April and May (for reasons outlined above), it is possible to make around 30% more silage per ha for more-or-less the same inputs costs compared to second-cut silage. Making a large first-cut lowers the need for second-cut silage. Therefore a smaller area needs to be closed for second cut. This makes a greater area available for grazing providing substantial scope to lower fertilizer N inputs onto the grazing area from June onwards.

When it comes to lowering fertilizer N input to the grazing area from mid-summer onwards, one question that often arises is whether to make large applications of fertilizer at long intervals, for example, 40 kg N/ha applied once ever eight weeks, or a smaller application at shorter intervals; 20 kg/ha every four weeks. Our experience is that small and regular applications help to maintain regular supply of high quality pasture. Large applications at long intervals result in a boom-and-bust situation where grass starts to run out of control, often triggering the decision to harvest bales, and then the grass begins to disappear because there is not enough N available in the soil. Applying rates of 15 to 25 kg N/ha (around half a bag of CAN/acre) at four to six-week intervals during the summer is recommended on moderately stocked farms (Table 4).

Atypical situations

The biggest problem with making recommendations is that most farms are not average or typical in terms of soil type, land use (for example, growing maize instead of first-cut or second-cut silage), the extent to which farms are fragmented, etc. In Table 5, fertilizer N rates are recommended for different stocking rates on the grazing area at different times of the year. For example, on a fragmented farm, where a large part of the silage requirement is made as maize silage grown on an outside block of land, the stocking rate on the grazing area on the home farm during May and June is relatively low and hence the requirement for fertilizer N during this period can be quite low. Putting on too much fertilizer N is only going to drive up costs if excessive grass production on the grazing area has to be harvested as baled silage. The recommendations in Table 5 should only be used as part of an overall plan that keeps fertilizer use on the farm compliant with the maximum permissible rates outlined in Table 1.

Table 4. Recommended rates of fertilizer N for grassland during the year where approximately half of the farm is cut for first-cut silage and the amount of second cut is kept to a minimum (0 – 30% of the grassland area). Rates of fertilizer N are presented in kg per ha (units per acre in brackets)

Stocking rate (kg/ha organic N)	Jan/Feb	March	April	May	June	July	August	September	Total (kg/ha)	Total (u/ac.)
155 – 170	0	28 (23)	43 (35)	34 (28)	34 (28)		25 (20)		164	(133)
170 – 180	28 (23)	28 (23)	43 (35)	34 (28)	34 (28)		25 (20)		192	(156)
180 – 190	28 (23)	37 (30)	49 (40)	34 (28)	34 (28)		34 (28)		216	(175)
190 – 200	28 (23)	49 (40)	49 (40)	34 (28)	34 (28)	34 (28)		25 (20)	253	(205)
200 – 210	28 (23)	49 (40)	49 (40)	51 (41)	34 (28)	34 (28)		34 (28)	279	(226)
211 – 250	28 (23)	43 (35)	49 (40)	34 (28)	34 (28)	34 (28)		25 (20)	247	(200)

The recommendations in this table are for farms on soils of average natural fertility. At stocking rates less than 200 kg organic N/ha substantially more fertilizer N than is recommended in this table can be applied on poorer soils to adequately meet sward requirements. Less fertilizer N than recommended in this table is needed on soils with above average natural fertility or where there is plenty of clover in the sward.

At very high stocking rates of greater than 200 kg organic N/ha slightly more fertilizer N (for example 8 kg/ha) than is presented in this Table can be applied in southern counties (see Table 1) and this should be applied in spring as part of the first or later applications.

Table 5. Fertilizer N for different stocking rates on the area available for grazing during the year. Rates of fertilizer N are presented in kg per ha (units per acre in brackets). Care is needed when using this table not to exceed statutory limits outlined in Table 1.

Stocking rate (LU/ha)	Fertilizer N kg/ha (u/ac.)		Stocking rate (LU/ha)	Fertilizer N kg/ha (u/ac.)		Stocking rate (LU/ha)	Fertilizer N kg/ha (u/ac.)			
Mid March	Jan/Feb	March	May & June	April	May	July & August	June	July	August	September
<1.2	0	28 (23)	<3.50	28 (23)	17 (14)	<2.00	17 (14)		17 (14)	
1.2 – 1.4	28 (23)	28 (23)	3.50 – 3.75	28 (23)	26 (21)	2.0 – 2.5	26 (21)		25 (20)	
1.4 – 1.6	28 (23)	38 (30)	3.75 – 4.00	38 (30)	34 (28)	2.5 – 3.0	34 (28)		34 (28)	
1.6 – 1.8	28 (23)	49 (40)	4.00 – 4.25	49 (40)	42 (35)	3.0 – 3.5	34 (28)	26 (21)		25 (20)
>1.8	28 (23)	49 (40)	>4.25	49 (40)	51 (41)	>3.5	34 (28)	34 (28)		34 (28)

New regulations and old recommendations for grassland

It can be seen in Table 3 that the soil at Solohead has the capacity to supply around 140 kg background N/ha during the main growing season (mid-February to late October; a further 25 kg/ha is released during the winter period). This is similar to the national average. Taking into account the range in background availability of N from different soils, it is obvious that the fertilizer N recommendations in Table 4 are likely to be too low on farms with soils with low levels of background availability and too high on farms with high levels of background availability. Therefore the Teagasc recommendations serve to indicate the quantities of fertilizer N that are likely to be required in an average situation. It is not possible at the present time to be able to accurately delineate the extent to which the soil on a particular farm is able to supply background N.

There has always been a need for some flexibility in the quantity of fertilizer N needed for different stocking rates because the amount of fertilizer N needed can vary with the natural fertility of soils, growing conditions in a particular year, etc. The new limits on fertilizer N use are compared with the old Teagasc recommendations in Figure 10, where the dashed lines represent the range in fertilizer N requirements that might be needed on different farms. At stocking rates less than 200 kg/ha of organic N (approximately 2.35 LU per ha or 0.95 LU per acre) the new limits are higher than the old recommendations and allow a fairly wide degree of leeway when it comes to fertilizer N use. The vast majority (>95%) of grassland farmers in Ireland are stocked at less than this. The new limits should not pose a serious problem for these farmers as long as they keep an eye on how much fertilizer N is being used.

For farms stocked between 200 and 210 kg/ha of organic N (2.35 to 2.50 LU per ha or 0.95 to 1.00 LU per acre) the new limits are higher than the old recommendations but there is little scope to use higher rates. Farms at these stocking rates on naturally fertile soils should be able to comply with the new recommendations without difficulty. Keeping records is important under the new regulations.

On highly stocked farms (211 to 250 kg organic N per ha; 2.5 to 3.0 LU per ha or 1.0 to 1.2 LU per acre) the new regulations pose a serious challenge for these farmers. On soils with high natural fertility, planning and attention to detail when it comes to managing fertilizer N and slurry should be sufficient to ensure that fertilizer N use complies with the limits. High milk output per cow is obviously important on these farms.

Nevertheless, most farmers have a fair idea of the background fertility and production capacity of their farms. It is fairly obvious when not enough fertilizer is being applied on the farm; not enough grass is being grown. It is also fairly obvious when too much fertilizer is being used; when excessive quantities of surplus grass is being baled during the second half of the growing season. It pays to cut back on fertilizer N under such circumstances.

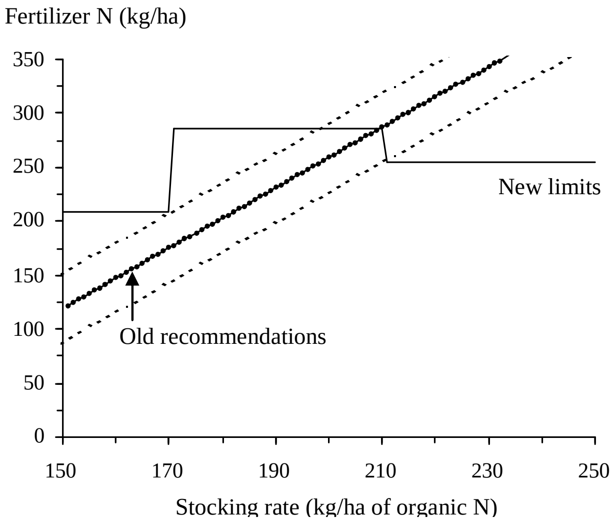

Figure 10. Comparison of the new limits and the old fertilizer N recommendations (dashed lines represent range of fertilizer N needed on different farms due to soil type etc.

Fertilizer N application in spring and autumn

Strategies for the application of fertilizer N during the spring have been outlined above. However, a question that often arises is whether it is better to apply CAN or urea during the spring. Numerous experiments have been conducted comparing the two. In all cases CAN was never found to be better than urea under Irish conditions whereas urea was sometimes better than CAN. The reason for this is fairly clear. Once urea is applied to the soil during the spring it is converted to ammonium. The ammonium is held reasonably well to the soil particles. In contrast, CAN contains both nitrate and ammonium and the nitrate is immediately at risk of being leached or denitrified. Furthermore, some recent research has shown that ammonium is more easily taken up by nitrate under cold soil conditions. Urea is cheaper than CAN per unit of N applied. Taking into account that the N in urea is used as efficiently as the N in CAN during the spring, urea is clearly the more cost-effective fertiliser to apply during the spring.

It must be noted that while it takes time for urea to break down to ammonium and that the ammonium adheres reasonably well to soil particles, any ammonium that is not taken up by the sward will be eventually converted to nitrate in the soil. Therefore the application of urea fertilizer does not prevent nitrate leaching or denitrification during the spring. It just means that the N in urea is likely to be safely held in the soil for longer than the N from a similar application of CAN, during the early spring.

The responsiveness to fertilizer N declines during the autumn. The reasons for this have been outlined above. In general, research has shown that there is no worthwhile response to fertilizer N from around mid-September onwards in the southwest and from around the end of August in the north. Conditions may often seem ideal for the application of fertilizer N later in the year. However, when fertilizer is being applied during the early spring, it is being applied in anticipation of expected growth. When fertilizer is being applied during the autumn, growth is inexorably declining. Also, not all of the applied N will be taken up in one go. Fertilizer applied in mid-September will be taken up at a rate of around 0.5 kg N/ha/day during the remainder of September and October. Therefore, it takes around 60 days for 30 kg N/ha to be taken up from the soil. By mid-November, the requirement for fertilizer N will be very low and will be within the supply capacity of the background N (Figure 7). Therefore as the application of fertilizer N is delayed into late September or October the demand for available soil N is disappearing while the risk of loss increases exponentially.

The application of slurry

On most farms, management of slurry is more of a headache than anything else and is usually seen as a non-productive cost. However, when it comes to spreading slurry, it generally costs as much to apply slurry under conditions that give maximum response to the nutrients in that slurry as it does to apply the slurry under conditions that give poorest response (Table 6). Many farmers have traditionally applied slurry after first-cut silage and the remainder after the last grazing rotation during October and November. The contribution of the N in this slurry to grass production is almost zero. Most of the available N in slurry applied to silage stubble during the summer is lost by volatilization. The utilization of nutrients in slurry applied in the late autumn and early winter is so low that the cost of applying the slurry exceeds the economic response to that slurry in terms of grass growth and subsequent animal performance. Holding slurry over until the following spring (late January to April) will greatly improve the efficiency of nutrient use within that slurry and the cost effectiveness of slurry application.

The best response to slurry is obtained during the spring. In many ways slurry is an ideal source of N for application during the spring. Half of the N is in the form of ammonium, which is not readily leached and is more easily taken up under cold conditions. The other half of the N is in the form of organic matter, which is very effectively held in the soil. This material has to rot away before the N is made available for uptake by the sward. The rate of release of the N in the organic material therefore increases with rising soil temperatures making N available in line with increasing grass growth. Slurry can be used very effectively to replace fertilizer N for the first application in spring. There are clear benefits associated with this. It can be seen in Table 6 that the net value of this slurry is around €5/ha (€2/acre). In contrast, applying slurry during the late autumn or early winter will result in poor utilization of the nutrients in the slurry. Under such circumstances the net cost of the disposal of this slurry is approximately €28/ha (€11/acre). On a 40 ha (100 acre) farm this difference in slurry management amounts to well over €1000 per year.

Table 6. The impact of date of application on the utilization efficiency of the nutrients in cattle slurry, the gross value of the slurry (replacement value of artificial fertilizers) applied at a rate of 33 cubic metres/ha (3000 gals/acre) and the net cost or saving of the slurry assuming that the cost of applying the slurry is €75/ha (€30/acre)

	Nitrogen	Phosphorus	Potassium	Gross Value*	Net cost or saving
Nutrients per cubic metre (kg)	3.2	0.5	3.0		
Value of Nutrient (€/kg)	0.65	1.40	0.40		
	Utilization efficiency (%)			(€/ha)	
Spring (ideal)	50	100	100	97	22
Spring & September (typical)	25	100	100	80	5
Spring & September (poor)	15	100	100	75	0
May to August	5	100	100	66	-9
October to January	10	90	50	47	-28

*Based on the replacement value of artificial fertilizer

This value is based on the cost of replacing the nutrients in the slurry by artificial fertilizers that are used with high efficiently. It does not reflect the value of the nutrients in slurry when converted into pasture or into the animal products, such as milk, sold off the farm. If the nutrients in slurry were valued on this basis, the magnitude of difference between efficient use or disposal of slurry on the farm becomes much greater. The message is clear; it pays to get as much of the slurry generated on the farm applied in spring.

Making better use of slurry

There are three opportunities to apply slurry in spring (i) in late January or early February before livestock are turned out to grass, (ii) after grazing during February and early March when there is a long interval (at least six weeks) before the next grazing and (iii) in late March for first-cut silage. In general, recovery of N in slurry applied later in the year will be relatively poor. It costs the same to apply slurry during the spring as it does later in the growing season. Applying slurry in spring gives most cost-effective use of the nutrients in the slurry.

During the spring at Solohead, the entire farm is grazed between early February and mid-April. By late January, the tanks are getting fairly full with slurry. This slurry is applied to around two-thirds of the farm during late January or early February; the other one-third of the farm is used for grazing during February and early March. The slurry at Solohead is stored in outdoor earthen-bank tanks and contains around 4% DM. This diluteness of the slurry combined with high rainfall during this period ensures that the slurry is washed off the grass a long time before the cows come around to grazing, which is generally between five and ten weeks later. We have seen a good response to this slurry. With an application of around 28 cubic metres/ha (2500 gals/acre), it is estimated that this contains a total of around 75 kg N/ha, around 35 kg/ha of this is readily available as ammonium N. Around 20 kg/ha is taken up by the sward. The remainder of the ammonium N is unavoidably lost. This application of slurry replaces the 29 kg N/ha applied as urea fertilizer (much of which will also be unavoidably lost; see Figure 5 & Figure 7) recommended in Table 4. This application of slurry does not seem to have any detrimental effect on the acceptability of the grass to the cows.

During March and April, around half of the farm is closed up for first-cut silage. At this stage the slurry tanks are getting quite full again. Slurry is applied to around two-thirds of the silage ground during the first week of April. The other one-third of the silage ground remains to be grazed during April to complete the first rotation at some stage during the second or third week of April. The first week of April is the targeted because a lot of the silage ground will have been grazed at that stage and, assuming that the silage is harvested towards the end of May, there will be around seven weeks between application of the slurry and the harvest of silage. This lowers the risk of contamination of the silage. An application of around 33 cubic meters of slurry/ha (3000 gals/acre) supplies around 100 kg N/ha, 50 kg of which is available in the form of ammonium N. It is estimated that the sward takes up around 25 kg of this, the remainder being lost primarily by volatilisation. The amount of fertilizer N applied for first cut silage is cut back accordingly from around 115 kg/ha to around 90 kg/ha. The excessive supply of N for silage may result in poor preservation. It is better to be cautious when it comes to applying N for silage and get a slightly lower yield of good quality silage than a larger yield of poor quality material.

During the winter, dirty water is applied using a rota-rainer in the paddocks nearest the farmyard. This dirty water is very dilute because it is being generated during a time of high rainfall and the cows are not being milked between Christmas and late January. Following the application of slurry to the silage ground during early April, any dirty water generated is pumped directly into the slurry tanks and mixed with the slurry. This has the advantage of reducing work because there is no need to keep moving the rota-rainer etc. It also has the advantage of lowering the loading of dirty water on the paddocks around the yard. This fairly dilute mixture of slurry and dirty water is applied to the silage ground after first-cut silage. Any dirty water generated during the second half of the year is applied on ground harvested for second-cut or for baled silage. An important objective is to ensure that the tanks are empty before the winter. Most of the slurry at Solohead is applied by contractors using an umbilical system, which is facilitated by the farm at Solohead being all in one block.

On-farm research has shown that by applying the slurry in a planned way in spring, farmers have been able to cut fertilizer N use by approximately 10% and probably accounts for some of the difference in the efficiency of fertilizer N use between different farms outlined in Figure 3. This saving in expenditure on fertilizer N is made only if the slurry is used to replace fertilizer N. Realisable targets are to have 70% of slurry applied before early April and 100% by mid June at which point tanks should be virtually empty.

White clover

While different ways of cutting back on fertilizer N have been outlined above, by far the biggest savings in fertilizer N costs that can be made on many farms is by growing white clover. White clover is an unusual plant in that it has the capacity to generate it own supply of N through a process known as biological N fixation. It can supply the equivalent of 120 to 150 kg/ha of fertilizer N (100 to 120 units per acre) per year. This is a lot of N when it is considered that average fertilizer N use on dairy farms in Ireland is around 170 kg/ha (140 units per acre) per year. White clover offers huge potential to cut fertilizer N costs on farms. The supply of 100 to 120 units of N is the equivalent of 3.5 to 4.5 bags of CAN. With CAN costing €225 per tonne, this supply of biologically-fixed N is worth €40 to €50 per acre. Growing white clover is a bit like having your own fertilizer N factory on the farm and this N can be manufactured at relatively little cost. It provides the opportunity to sidestep the escalating price:cost squeeze described in Figures 1 and 2 above.

Research at Solohead over the last seven years has shown clover-based grassland receiving fertilizer N input of 72 units per acre can support a stocking rate of 0.8 LU per acre (2.0 LU/ha or 170 kg/ha of organic N) and producing 500 kg milk solids per cow while being fed less than half a tonne of concentrate per cow per year. This is a high stocking rate and milk output per acre compared with the majority of dairy farms in Ireland. Obviously the N supplied by the white clover makes an important contribution to sward productivity. The other advantages of white clover are high sward nutritive value under low fertilizer N input and compatibility with REPS.

The big problem has been lack of persistency of white clover under Irish conditions. There are many reasons for this including the use of herbicides and high rates of fertilizer N. However, the fundamental problem is that white clover has an average life expectancy of around five years in grassland managed to promote productive white clover. White clover cannot be seen to be persistent in the same way as permanent grassland. Individual clover plants die off and need to be replaced at regular intervals, rather like bringing replacements into a herd of cows. Ongoing research at Solohead has shown that this can be achieved at very little cost by mixing white clover seed with a P&K fertilizer and spreading it onto first-cut silage stubble using a fertilizer spreader. Around one-fifth of the farm is over-sown on a five-year rotation. This maintains highly productive white clover swards from year to year. On-going research is showing that this approach is also working well on a number of farms.

The more fertilizer N that is applied the less N the clover will supply and therefore fertilizer N applications should be restricted mostly to the springtime when the clover is relatively inactive. Excessive fertilizer N use will eventually drive the clover out of the sward. Tight grazing promotes the clover content of the sward and increases sward productivity by making more N available in the soil. Grazing swards out well during the autumn and winter is important to promote productivity during the following growing season. For this reason clover is most suited to farms that can be grazed over a long grazing season.

White clover has a shorter growing season than perennial ryegrass. Perennial ryegrass grows slowly during the winter and growth rates increase rapidly during March. White clover lies dormant over the winter and does not begin to show substantial amounts of growth until April. Because of this some people have the impression that grass-clover swards have a lower capacity to supply grass during the springtime. This is not something that we have found at Solohead; we have had the same turn-out dates and grazing days per year from grass-clover and grass-only swards at the same stocking rates. In New Zealand white clover is an important component of swards and livestock are kept at pasture right throughout the year.

During the spring virtually all of the growth of grass-clover swards comes from the grass component of the sward. It is important during the spring to apply fertilizer N to drive on grass growth. Grass-clover swards should receive two or three applications of 23 units of urea per acre between mid-January and the end of April. High covers of grass during the spring can cause the loss of clover due to shading. It is important that light gets down to the clover at the base of the sward. Tight grazing is very important to promote clover survival. It has been shown that grazing to a post-grazing height of 4 cm can increase the production from grass-clover swards by over 20% compared to lax grazing (Figure 11). Tight grazing favours clover survival over the winter leading to more clover in the sward during the following growing season. More clover leads to higher biological fixation of N and this drives up overall production from both the grass and clover. Tight grazing also creates swards with very high nutritive value. In New Zealand very tight grazing to 3.5 cm known as "golf-ball grazing" is an important component of managing grass-clover swards. The overall impact of this system of grazing management on the productivity of clover-based dairy production is currently being evaluated at Solohead (2007 to 2009).

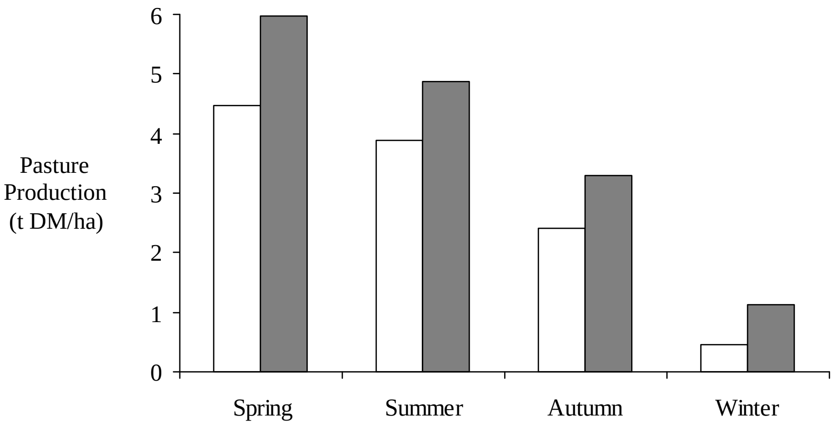

Figure 11. Lax (□) compared to tight (■) grazing and annual DM production from white clover – based swards in New Zealand

It is important to stop applying fertilizer N from late April onwards. During May biological N fixation by the clover supplies enough N for high levels of pasture production. No more fertilizer N is needed for the remainder of the year. This is where big savings in fertilizer N are made. The clover content of the sward increases from 5 to 10% during April to up to 40% during August. Clover stolon grows along the ground at the base of the sward in much the same way as ivy grows up a wall. There is a five-fold increase in the amount of this stolon during the summer months. Much of this stolon dies back over the winter releasing N into the soil that becomes available during the following spring. Therefore even though the clover is dormant during the winter and early spring it has the capacity to supply N right throughout the year.

Where does clover fit in?

Tight grazing over the winter is important to promote clover survival and therefore clover is recommended for farms where it is possible to graze livestock over a long grazing season. It is not suited to farms where livestock cannot be turned out early to grass or where it is difficult to graze out swards to a low post-grazing residual. Biological N fixation requires a high soil pH and therefore clover is not suited to peat soils that have naturally low pH. On many farms with low stocking rates and low fertilizer N usage there is little incentive to adopt clover because expenditure on fertilizer N is small and therefore there is little to be gained by growing clover to replace fertilizer N. Clover has most potential on moderately to high stocked farms where fertilizer N is an important input.

Clover can make a useful contribution to cutting fertilizer N costs on more intensive farms if the clover is grown on a portion of the farm. For example, on a 50 ha (125 acre) farm stocked at 2.25 LU/ha (0.9 LU per acre), fertilizer N use in the absence of clover needs to be approximately 230 kg/ha (185 units per acre), which is the equivalent of 42 tonnes of CAN for the whole farm each year (only CAN is used in this example for simplicity). However, if half the farm was under clover-based swards receiving low inputs of fertilizer N (58 kg/ha or 46 units per acre per year) and the other half under grass-only receiving 285 kg/ha of fertilizer N or 230 units per acre per year, overall fertilizer N use on the farm is lowered to the equivalent of 31 tonnes of CAN. This is a reduction in fertilizer N use of approximately 25% or a saving of approximately €2,500. The saving in fertilizer N is mostly of CAN used from May onwards; urea is used on both types of sward in spring.

Application of P and K fertilizers

When it comes to the application of P and K fertilizers and slurry it is important to base the rate of application on a recent soil test. Ideally around one-fifth of the farm should be sampled each year on a five-year rotation. This means dividing the farm up into five blocks of land. The management of the paddocks in each block should be reasonably similar. Each block should contain around 5 paddocks or so. One paddock within each block should be sampled each year on a rotational basis. This means that each paddock is sampled at an interval of around 5 years. This is a useful way of keeping track of what is happening within each block from year to year and within each paddock every 5 years or so. Comparing records over time provides very useful information on nutrient management on the farm such as better targeting of the P and

K value of slurry to where it is needed and avoiding unnecessary applications of P and K fertilizers.

As with slurry and fertilizer N, applications of P and K should be avoided during the late autumn to avoid losses over the winter. Applications of K during the early spring to any ground used for grazing should be avoided in order to lower the risk tetany. Silage has a huge requirement for K compared to grazing ground. Where it is necessary to apply K for silage it is better to wait until after grazing and to apply it when closing up during March or early April. Much of the requirement for K by the silage can be met by the application of cattle slurry, which contains large amounts of K. An application of 33 cubic meters of slurry/ha (3000 gals/acre) supplies around 90 kg K/ha (72 units per acre). It is also good practice to apply slurry after harvesting the silage to redress any imbalance in P and K taken off in the harvested silage. Mid-summer is also a good time to apply K to grazing ground as there is much less risk of tetany. Spaced applications of compound fertilizers such as 24-2.5-10 help to supply small amounts of K during the summer and are reasonably cost-effective as long as there is also a requirement for P in the soil. The controlled use of K fertilizer and cattle slurry can also be used to help keep docks under control. However, best control will be achieved when paddocks are alternated between silage and grazing from one year to the next. Continually harvesting silage from the same field generally leads to the deterioration of the sward and docks running out of control.

Phosphorus

The limits on Phosphorous (P) use on grassland under the Nitrates Directive are outlined in the SI 378, 2006 in terms of available P. Available P includes the P in slurry generated by grazing livestock on the farm, in concentrates fed to grazing livestock and in manufactured fertilizer as well as P in any organic manures (for example, pig and poultry slurry, dairy sludge etc.) imported onto the farm. A number of steps need to be taken to interpret available P in terms of the amount of fertilizer P that can be applied on the farm. The first step is to determine the soil P status through soil testing. This is compulsory on REPS and Derogation farms. Where there are no soil test results available on non-REPS and non-Derogation farms it is assumed that the soils on the farm are in Soil P Index 3. The second step is to deduct out the P in slurry generated by grazing livestock and stored over the winter. This ‘stored slurry’ is a notional quantity based on the statutory requirement for slurry storage on the farm (16, 18, 20 and 22 weeks depending on location). A rough guide to quantities of P that can be applied on farms with different stocking rates in different parts of the country is presented in Table 7.

Table 7. Approximate rates* of fertilizer P allowed in different parts of the country after deducting P in slurry generated by livestock but before deducting the P in concentrates fed to livestock. Examples of quantities of P in concentrate are at the bottom of the Table. Rates of fertilizer P are presented in kg per ha (units per acre in brackets)

Soil P Index	Grassland stocking rate (kg/ha of organic N per year)			
	≤130	131 – 170	171 – 210	211 – 250
		Zone A		
1	28.9 (23.4)	31.0 (25.1)	34.1 (27.6)	37.2 (30.2)
2	18.9 (15.3)	21.0 (17.0)	24.1 (19.5)	27.2 (22.1)
3	8.9 (7.2)	11.0 (8.9)	14.1 (11.4)	17.2 (14.0)
4	0.0	0.0	0.0	0.0
		Zone B		
1	28.1 (22.8)	30.0 (24.3)	32.9 (26.6)	35.8 (29.0)
2	18.1 (14.7)	20.0 (16.2)	22.9 (18.5)	25.8 (20.9)
3	8.1 (6.6)	10.0 (8.1)	12.9 (10.4)	15.8 (12.8)
4	0.0	0.0	0.0	0.0
		Donegal/Leitrim		
1	27.4 (22.2)	29.0 (23.5)	31.6 (25.6)	34.3 (27.8)
2	17.4 (14.1)	19.0 (15.4)	21.6 (17.5)	24.3 (19.7)
3	7.4 (6.0)	9.0 (7.3)	11.6 (9.4)	14.3 (11.6)
4	0.0	0.0	0.0	0.0
		Cavan/Monaghan		
1	26.6 (21.5)	28.0 (22.7)	30.4 (24.6)	32.8 (26.6)
2	16.6 (13.4)	18.0 (14.6)	20.4 (16.5)	22.8 (18.5)
3	6.6 (5.3)	8.0 (6.5)	10.4 (8.4)	12.8 (10.4)
4	0.0	0.0	0.0	0.0
Concentrate (t/LU)	Amount of P in concentrates fed to livestock (this must be deducted from fertilizer P above)			
0.5	3.9 (3.2)	5.1 (4.1)	6.3 (5.1)	7.5 (6.1)
1.0	7.8 (6.3)	10.2 (8.3)	12.7 (10.2)	15.1 (12.2)

*The rates in this table are a rough guideline to permissible rates and are presented for the purposes of example. Rates of P fertilization that can be used on individual farms need to be based on the specific details of each farm.

The next step is to deduct the P in concentrate fed on the farm. Examples of the quantities of P in concentrate where 0.5 and 1.0 t of concentrate are fed per LU are presented at the bottom of Table 7. Taking, for example, a farm in Zone A stocked at between 1.5 and 2.0 LU/ha (130 – 170 kg per ha of organic N) and there are no soil test results available. Hence, it is assumed that soils on the farm are in Soil P Index 3. No organic manure is imported onto the farm in this example. The amount of fertilizer P that this farmer can apply assuming that no concentrate is being fed on the farm is approximately 8.9 units of fertilizer P per acre. If half a ton of concentrate is fed per LU on the farm, this farmer is allowed to apply 4.8 units of fertilizer P per acre (8.9 units minus 4.1 units in concentrate). If one ton of concentrate is fed per LU, this farmer is allowed to apply 0.6 of a unit of fertilizer P per acre – in other words – virtually none at all.

To put this in context applying one bag per acre of pasture sward contains 2.5 units P per acre. One bag per acre of 18:6:12 contains 6 units P per acre. Even where only half a ton of concentrate is being fed per LU, one or two bags per acre of compound fertilizer can result in fertilizer P use on the farm exceeding the statutory limits. Average concentrate feeding on Irish dairy farms is approximately three quarters of a ton per LU. On many autumn-calving dairy farms where more that one ton of concentrate is being fed per LU, it is likely that no fertilizer P can be applied on the farm unless the soils on the farm have low soil P status (Soil P Index 1 or 2). If organic manure is imported onto the farm, the P in this manure is further deducted from the quantity of P allowed under the regulations.

Summary

Escalating costs and regulations under the Nitrates Directive are creating pressure to lower fertilizer inputs and increase the efficiency of nutrient-use on farms in Ireland. Increases in efficiency are possible once there is a clear understanding of the factors that promote the efficient uptake of available nutrients from the soil by grassland. The following are ten ways to cut fertilizer N costs on the farm:

1. Apply 23 units/acre (29 kg/ha) for the first application in spring (mid-January to early March depending on location and soil type etc.). Urea is more cost effective than CAN in spring.

2. Replace the first application of fertilizer N by an application of watery slurry. 1000 gallons of watery slurry = 8 to 10 units of N per acre. At Solohead around 2,500 gallons per acre are applied on two-thirds of the farm in late January using an umbilical system. The other one-third is grazed during February and early March. Allow around six weeks between application and expected date of grazing.

3. Apply the second application of fertilizer N between 6 and 4 weeks after the first. A 6-week interval should be allowed with earlier start dates (mid-January) and a

4-week interval with later application dates (mid-February). The second application should take place sometime during March. The third application should roughly coincide with closing up for silage in April. Match fertilizer N applications to stocking rates on the farm at various times of the year (see Table 4 & 5).

4. Replace some of the fertilizer N for first cut silage by slurry. If 92 units per acre (115 kg/ha) is applied for first cut silage, this can be lowered to around 69 units per acre (85 kg/ha) along with an application of 3000 gallons slurry per acre. At Solohead 3000 gallons per acre is applied to around two-thirds of the first-cut silage area in late March (this is the proportion of the silage area that will have been grazed at that stage). The slurry is applied allowing at least 6-weeks between application and expected silage harvest date. An interval of around one week is allowed between application of slurry and the application of fertilizer N for first-cut silage. Don't apply the fertilizer N immediately before or shortly after the slurry because this leads to losses of N by denitrification.
5. Try to make as much of your silage as possible as first cut. Firstly work out how much silage is required. Secondly, depending on requirements, aim to maximise stocking rate on the grazing area during April and May. This makes as large an area as possible available for first-cut silage. There is a very high response to fertilizer N during April and May. First cut silage yields will be at least 30% higher than second cut for more-or-less the same input costs. High grazing pressure on the grazing area during April and May is good for grass quality later in the season.
6. Diluting slurry with dirty water will increase the efficiency of utilization of N in the slurry when it is applied to silage stubble after first-cut silage. Although dilution will lower the DM and N content of the slurry, it will increase the efficiency of N utilization (a higher rate of infiltration into the soil lowers volatilization losses). Dilution should only be carried out where it is a convenient means of managing dirty water and at times of the year outside of the closed period for slurry application.
7. Avoid making second cut silage, if possible. Having the whole farm available for grazing from June onwards lowers the requirement for fertilizer N. Apply fertilizer N in line with stocking rate (Tables 4 & 5) and also pasture cover. If pasture cover is above target, lower the amount – or increase the interval between applications – of fertilizer N. Do not skip applications.
8. Plan to build pasture cover by extending out the rotation from mid- to late-July depending on stocking rate and location (later on higher stocked farms in more favourable locations and vice-versa). Fertilizer N applied in July and August has

greater bearing on grass supply in November and in the following spring than applications later in the autumn.

9. KEEP RECORDS of quantities and dates of application – and study them. Blanket spreading of fertilizer N simplifies record keeping and this helps to keep overall fertilizer N use on the farm under control (this can bring about a considerable saving in annual fertilizer N use while also lowering baled surpluses). The first three applications during the spring (during calving) and applications during August and September can be blanket spread with no loss of production. Blanket spreading during the summer months can result in slight (3.5%) lowering of production.

10. WHITE CLOVER has the potential to supply up to 120 kg N/ha/year through the fixation of atmospheric N by Rhizobium bacteria that grow in symbiotic association with the clover. The wider adoption of white clover in Irish grassland has the potential to halve the amount of fertilizer N used on the majority of grassland farms in Ireland.

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Phosphorus for grassland: agronomically and environmentally sustainable advice.

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Introduction

In 2006, the Nitrates Directive (through S.I. 378 (Anon, 2006)) was implemented in Ireland, aimed at reducing nutrient losses from agriculture to water bodies, i.e. surface waters, groundwater and estuarine waters. This legislation introduced strict regulation of nutrient management on Irish farms. Thus far, nutrient management had largely been based on Teagasc advice (Coulter, 2004). However, in the new policy climate, in addition to advice, compliance with legal limits is also required.

This significant change in the practicalities surrounding nutrient management led to a review of Teagasc nutrient (phosphorus and nitrogen) advice, based on the following considerations:

Traditionally, nutrient advice had largely been based on fertiliser rates for economically optimal productivity, i.e. rates at which further fertiliser applications would not result in higher economic returns. Now, SI 378 of 2006 demands that nutrient application rates do not exceed crop (grass) demand, nor result in nutrient losses that may have a negative impact on water quality.

Previous phosphorus (P) advice (Coulter, 2004) was similar for all soil types, and did not account for potentially different P-requirements, or indeed potentially different risks of P-loss to water between soils.

Previous P advice was based on returning optimum crop yields. However, grassland management in Ireland is increasingly focussed on maximising the amount of herbage grazed *in situ*. With extended grazing seasons and an increasing share of the animal diet consisting of grazed herbage, the scope and flexibility of diet supplementation through straights and concentrates is reduced. An increasing proportion of dietary P must be obtained from this grazed herbage as a result. Therefore P fertiliser strategies should no longer be based on yield responses alone, but in addition sustain adequate herbage P-concentrations in order to ensure that the dietary P requirements can be met on a non-supplemented diet of grazed herbage.

Against this background, Teagasc, Johnstown Castle Environment Research Centre, undertook a major research programme, reviewing both agronomic and environmental aspects of P-advice for grassland.

Phosphorus agronomy

Rationale

P advice for grassland in the Republic of Ireland was based on a soil P-index system (Table 1), defined by soil-test P (STP) using Morgan's extractant. Soils in Index 1 are P-deficient, and require build-up of soil P-reserves. The optimum soil-test P ("target index") depended on farm intensity. A target Index of 3 was recommended where early grass was required and where herbage production is fully utilised. A target Index of 2 was recommended where the stocking rate was below the stock carrying capacity of the land. Soils in Index 4 have elevated P-reserves, and do not exhibit responses to additional fertiliser P.

Table 1. P Index system for grassland prior to SI 378 of 2006.

P Index	Soil Test P (mg/l, Morgan's)
1	0 – 3.0
2	3.1 – 6.0
3	6.1 – 10.0
4	Above 10.0

Phosphorus fertiliser advice for grassland has been based on:

1. Building up soil P reserves to the target index;
2. Maintaining soil-test P at the target index by replacing off-take of P in meat and milk;
3. Frequent (every 4-5 years) soil tests to ensure STP levels are maintained at the target index.

At the time, the introduction of this advice led to a marked reduction in fertiliser use, from *c*. 60,000 tonnes in 1994 to less than 40,000 tonnes in 2004, a reduction of a third over a decade (figure 1).

However, a review of soil test P levels revealed that up to 25% of samples received at Johnstown Castle laboratories were of soils in Index 4. This means that these soils had elevated soil P levels, i.e. levels at which fertiliser P application do not yield economic returns, yet at which risks of P-loss to the environment are considered to be increased. On these sites, agronomic and environmental management are synergistic, since withholding fertiliser P on index 4 soils saves both money for farmers and reduces risks of P-loss to water.

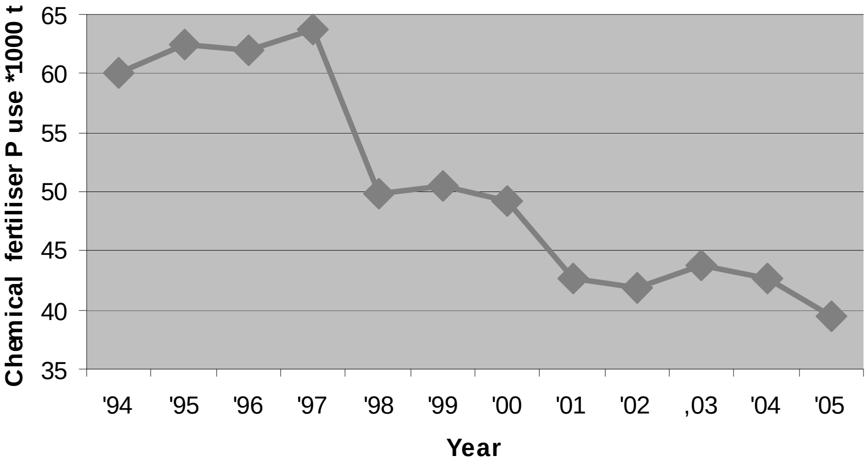

Figure 1. Usage of chemical fertiliser P from 1994 to 2005.

Materials and methods

In order to establish soil-specific responses of herbage production and herbage P concentration to fertiliser P applications and to STP, a large-scale agronomic experiment was carried out from 1997 to 2000. The experiment was conducted on eight contrasting soils (associations 13 and 15, series 14, 22, 30, 33, 34, 39 of the General Soils Map (Gardiner and Radford, 1980)), see Table and Figure 2. The objective of the experiment was to establish fertiliser P-application rates that return 95% of potential maximum yield and herbage P-concentrations of 0.30-0.35%.

Within each soil series, sites were selected representing the P indices 1, 2, 3 and 4, and fertiliser P was applied at rates of 0, 10, 20, 30, 40, 50, 60, 75, and 100kg/ha with two replications (four for 0kg/ha control). At each site, herbage was cut four times annually, and herbage DM yield and P concentration was established for each treatment. After each year, the experimental plots were re-randomised on a new location within each site, in order to prevent residual effects. Composite soil samples (20 sub-samples per plot) were taken twice annually (spring and autumn) at a standard depth of 10cm, and dried at 40°C. STP was measured annually using Morgan's extract (details in Herlihy *et al.*, (2004)). For each soil type, the annual herbage yield (kg DM/ha) and average herbage P concentration (g/kg DM) of each year were non-linearly related to the annual STP (mg /l) and fertiliser P rates (kg/ha) as analysed by multiple non-linear regression.

Table 2. Classification and selected characteristics of the soils used in this study (Gardiner and Radford, 1980; Herlihy *et al.*, 2004).

Series / association	No.	Principle soil	Parent material	Drainage	pH range	Location
Association-13	13	Acid brown earths	Sandstone-limestone diamicton	Good	5.0-6.4	Waterford
Clonroche	14	Acid brown earths	Ordovician shale diamicton	Good	5.8-6.5	Wexford
Association-15	15	Brown Podzolics	Sanstone-shale diamicton	Good	5.7-6.6	Cork
Castlecomer	22	Gleys	Upper Carboniferous (Silesian) shale diamicton	Poor	5.2-6.0	Kilkenny
Baggotstown	30	Grey brown podzolics	Calcareous fluvio-glacial gravel	Good	5.6-6.9	Offaly
Kinvarra	33	Shallow brown earths and rendzinas	Limestone diamicton (shallow)	Good	5.6-7.3	Galway
Elton	34	Minimal grey brown podzolics	Limestone diamicton	Good	4.8-6.5	Tipperary
Howardstown	39	Gleys	Limestone diamicton	Poor	4.9-6.3	Limerick

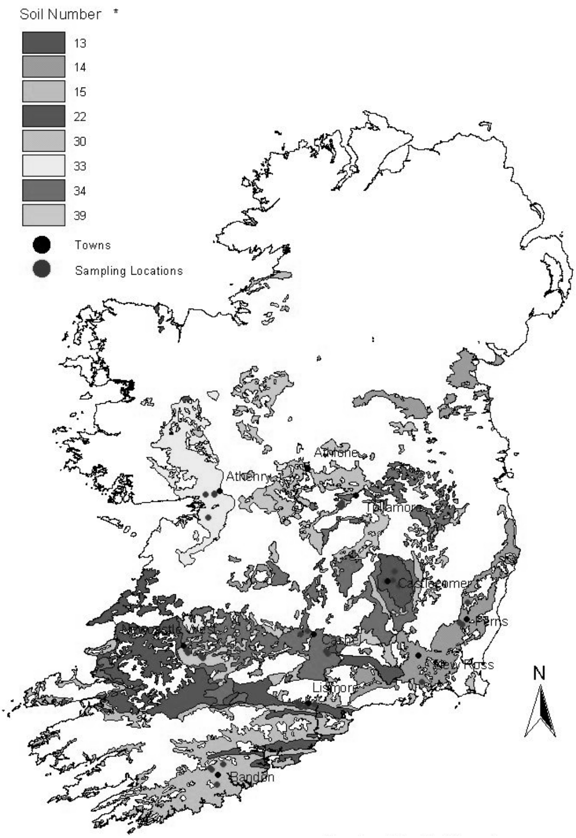

Figure 2. Map showing location of the soils represented by the experimental sites. Source: Gardiner and Radford (1980).

Results

Both fertiliser P and STP had a significant effect on both herbage yield and P-concentration (P < 0.0001). Together, STP, fertiliser P, and to a lesser extent year effects explained on average 34% (range: 9%-66%) of the variation in herbage yield, but more than double this percentage, i.e. 73% (range: 59%-86%) of the variation in herbage P concentration. This finding suggests that there is a strong relationship between soil P-levels and fertiliser P applications and the amount of P taken up by the grass. However, how this P-uptake is utilised and transformed into yield responses depends on additional external factors, e.g. meteorological conditions and botanical composition.

Figure 3a illustrates the P-fertilisation rates required to return a relative yield of 95% of potential yield. At Soil P Index 1, four soils required fertiliser rates between 10 and 40kg P/ha, with soils 34 and 22 requiring as much as 58 and 76kg P/ha, respectively. Soils 14 and 30 required only 3 and 0kg P/ha, respectively. At Soil P Index 2, the herbage yield responded to fertiliser P only on soils 22, 34 and 39, while at Soil P Index 3, substantial P-fertilisation was only required on soil 22.

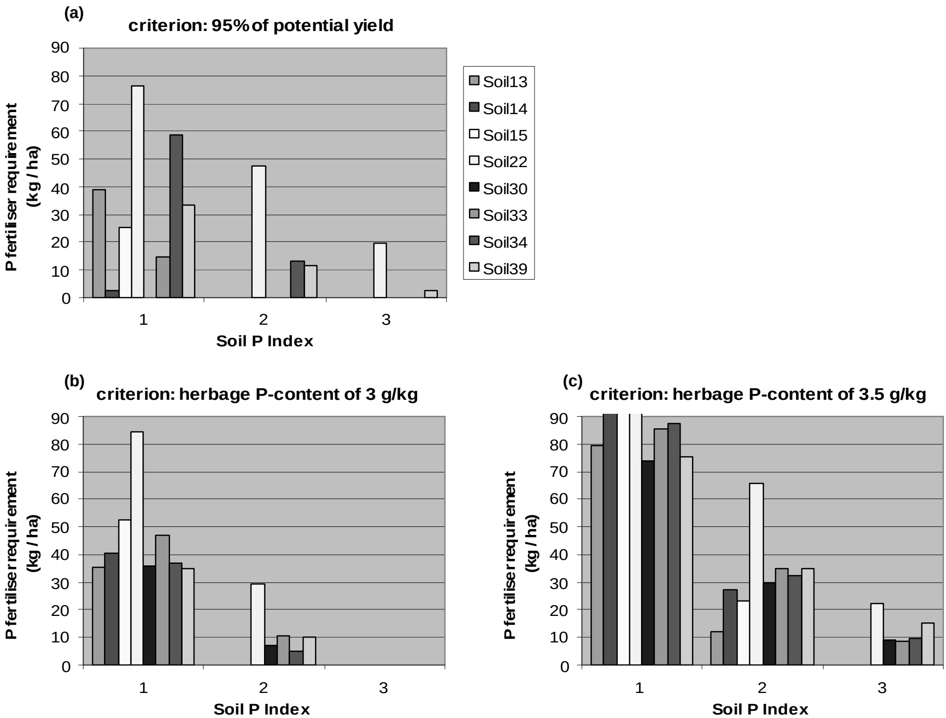

Figure 3. P fertiliser rates (kg//ha) required to produce a) 95% of potential yield; b) a herbage content of 3.0g/kg and c) a herbage content of 3.5g/kg for each combination of soil series and the "old" soil P index.

Figure 3b shows that for all soils, higher P fertiliser rates were required to reach herbage P contents of 3g/kg than for maximum yield. At Soil P Index 1, most soils required between 35 and 55kg P/ha, again with the exception of soil 22, on which as much as 85kg P/ha was required. At Soil P Index 2, these rates were reduced to less than 11kg P/ha on most soils, except for soil 22 which required 29kg P/ha. As with DM yield, no substantial fertilisation was required at Soil P Index 3.

Even higher rates were required to produce herbage P-contents of 3.5g/kg (Figure 3c), with all soils requiring over 70kg P/ha at Soil P Index 1, and between 12 and 35kg P/ha in Soil P Index 2, again with the exception of soil 22, which required as much as 65kg P/ha at Soil P Index 2. The 3.5g/kg P content target required modest fertiliser P inputs up to 15kg P/ha to be applied to Soil P Index 3 soils (22kg P/ha for soil 22).

The P-fertiliser requirements shown in Figure 3 are not to be equated to fertiliser P advice at farm scale; instead, these are the P-requirements under the experimental management regime imposed. The up-scaling of these experimental data to field and farm level should account for P cycling and P-dynamics at these higher scales, and in particular for the following:

The experimental plots in this study were cut four times annually. In practice, herbage is commonly defoliated either less frequently (silage) or more frequently (grazing). Cayley and Hannah (1995) showed that the responses of the relative yields to fertiliser P were identical for cut and grazed grass. However, herbage P content does decline with grass maturity. Data by Fleming and Murphy (1968) suggest that P contents remained high in herbage cut frequently (13 times annually), but declined by up to 2.5g/kg when grass was not cut until full maturity, though the precise quantification of this reduction in P contents is difficult to establish from their data. However, this suggests that in the current study, higher P contents may have been expected under more frequent defoliation.

The P requirements deduced in this study were total P-inputs. Since no organic P was applied to the experimental plots, these P-requirements equated to fertilizer P rates. However, at farm scale additional P is recycled, mainly in the form of manure and slurry produced over winter and dung deposited at grazing. To date, fertiliser P advice in Ireland has accounted for P in slurry and manure, by subtracting the latter from the total P requirements. P in dung, however, is deposited on only c. 5% of the grazing area each year, even on intensive dairy systems, and thus cannot be accounted for on the remaining 95% of the grazing area. Additional P may also be imported onto the farm in the form of concentrate feeds. However, from the above it follows only concentrate P fed during the housing period may be presumed available in the slurry.

For soils that have reached the target P index, P inputs should not be below maintenance rates, i.e. rates required to replace offtakes of P in the form of animal produce. Recently, Herlihy et al. (2004) showed that, on the soils used in their study, P application rates below maintenance requirements led to declining STP concentrations over time.

Implications for fertiliser P advice

Notwithstanding these uncertainties surrounding the up scaling of results to farm level, this experiment has produced the following consistent results:

In general, the fertiliser P rates advised by Coulter (2004) largely correspond to the P requirements observed in this experiment, with the exception of soil 22 (see point 3 below). The main discrepancy between current P advice and P requirements in this experiment involved the high P rates required to produce herbage P-content of 3.5g/kg on soils in Index 1 (Figure 3c). This warrants more detailed investigations into P chemistry at low indices, which is the subject of recent and ongoing studies (e.g. Herlihy & McGrath, (2007)).

P-fertilisation rates required to produce herbage P contents of 3.0 and 3.5g/kg, exceeded rates required to produce a relative yield of 95% of potential yield. In other words, where average herbage P content in excess of 3.5g/kg is observed, this implicitly confirms that a relative yield of 95% has been reached, irrespective of soil type. As a result, P fertiliser requirements are primarily determined by the need for adequate herbage P-concentrations.

These P requirements for herbage quality exhibit similar patterns for most of the eight soil series and associations in this study, with the notable exception of soil series 22. This non-limestone soil is characterised by its very poor drainage characteristics and high organic matter content. Attempts were made to explain differences between soils by auxiliary soil parameters, i.e. parent material, Hedley fractions, sorption parameters, pH and soil texture fractions, but no straight-forward, unambiguous relationships were found. Therefore, the results of this study do not support soil-specificity in agronomic P advice.

No dry matter yield responses to fertiliser P were observed at STP levels between 3 and 6mg/l (Figure 3b). However, where high herbage P-contents are required, large responses were observed at these STP levels. At levels between 6 and 10mg/l, small additional P concentration responses were observed, largely corresponding to maintenance application rates (Figure 3c). This suggest that the agronomic optimum for herbage P-concentrations approximates 6mg/l for farming systems with a demand for high grass quality (in terms of herbage P content), irrespective of demands for overall grass quantity (i.e. stocking densities).

For soils that are above the target Index, applications of fertiliser P are not required. The STP can be allowed to fall until it reaches the target Index, at which point application of maintenance rates of fertiliser P should resume. Regular soil testing is required the rate of decrease of STP concentration.

Phosphorus and the environment

Background

In comparison to nitrogen, phosphorus is largely an immobile element. The majority of phosphorus applied to grassland is either utilised by the grass crop, or firmly bound to soil particles at so-called "binding sites" through a process called adsorption. In grassland, most P is adsorbed in the upper few centimetres of the soil profile, and only a small proportion of the total soil P is available to plants, as measured by Morgan's P-test. However, at high soil P levels, the majority of high-energy binding sites may be utilised and further P additions may remain available in more labile forms. This phosphorus, when not taken up by the plant, is susceptible to being moved from soil to water by overland flow. Although quantities lost to water may be small in agronomic terms, losses of one or more kilograms of P per hectare may have undesired environmental side-effects and result in eutrophication of surface waters. Eutrophication is the process of nutrient enrichment of surface waters, which may lead to excessive growth of algae and produce algae mats. Rotting of this vegetation extracts oxygen from the water, which impacts negatively on the aquatic ecology and, in extreme cases, may lead to fish kills.

Water quality in Ireland

Compared to many parts of Europe, water quality in Ireland is generally good, with 88.3 % of river waters classified as "unpolluted" (70.2 %) or "slightly polluted" (18.1 %) by the EPA (Toner *et al.*, 2005). However, 30% of surface waters are subject to "moderate" or "severe" eutrophication. Recently, concerns are growing about the quality of our estuarine waters, with 22.4 % of our estuaries classified as "potentially eutrophic" or "eutrophic". Both the Nitrates Directive and the Water Framework Directive require that all surface waters are restored to reach "good" water quality status.

There has been an ongoing debate on the relative contribution of agriculture to eutrophication in comparison to other sources such as losses from municipal discharges and septic tanks. The precise contribution from agriculture is very difficult to quantify, but has been estimated to be approximately 70% (Stapleton *et al.*, 2000; EPA, 2004).

Environmental research

Phosphorus loss from soil to water, as well as mitigation strategies to reduce these losses, have been the subject of a very large research programme at Johnstown Castle, in collaboration with many Irish universities, and co-funded by the EPA. The outcomes of this programme can be summarised by the pressure pathway concept (Schulte *et al.*, 2006) illustrated in Figure 4. In summary, risk of P-loss to water occurs in circumstances where "P pressures", i.e. quantities of available P, coincide with transport mechanisms from soil to water.

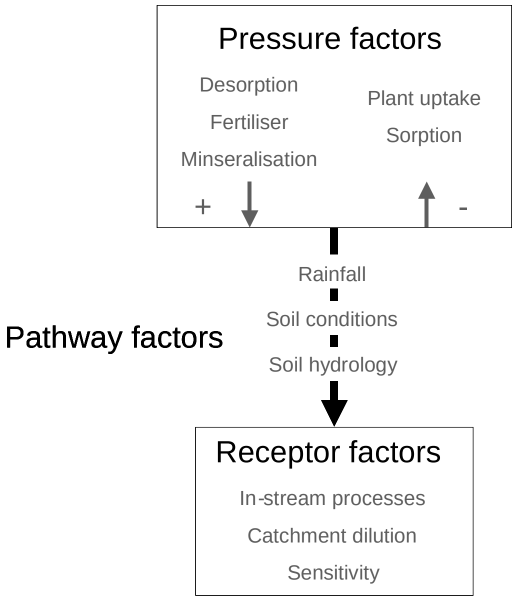

Figure 4. A conceptual model of P loss to water. Adapted from Schulte *et al.* (2006).

Pressure factors

Pressure may be defined as the balance between inputs and outputs of nutrients, i.e. inputs of fertiliser and organic nutrients, mineralisation and desorption on the one hand, and plant uptake and sorption on the other hand (Heathwaite *et al.*, 2003). Therefore, the pressure or the risk of nutrient P loss to water is determined by the size of the P surplus. The greater the surplus, the greater is the source pressure. It is now well established that soil P-levels are the main P-pressure factor. There is an unambiguous relationship between increasing STP levels in soils and increasing potential for P loss at plot scale (Sharpley *et al.*, 1981; McDowell and Condron, 2004), field scale (Kurz *et al.*, 2005a; Kurz *et al.*, 2005b) and sub-catchment scale (Daly *et al.*, 2002; Jordan *et al.*, 2005; Kurz *et al.*, 2005b) in Ireland. At high soil P levels, most of the high-energy binding sites have been utilised, and further P-additions are bound in more labile forms (Herlihy and McCarthy, 2006), which are more susceptible to desorption and transport through overland flow.

However, desorption processes are soil-type dependent, and the precise relationship between STP and risks of P-loss depends to a large extent on soil chemistry. In organic soils (peats and peaty soils), organic matter competes with P for binding sites. As a result, few binding sites are available for P (Daly and Styles, 2005), therefore the concept of “P build-up” is less applicable in these soils. On the other hand, increases in Fe^{2+}, Al^{3+} and Ca^{2+} concentrations in the soil generally favour P adsorption, so that soils with high concentrations of these ions have high capacities to bind and store P (Daly and Styles, 2005).

Pathway and Receptor factors

For high nutrient pressures to pose a significant risk to water quality, transport pathways have to be present in the form of surface overland flow that will transport the nutrients to water body receptor. Overland flow is generally caused by excess rainfall on saturated, poorly-drained soils (Diamond and Sills, 2001; Kurz, 2002; O'Reilly, 2006). Phosphorus can then become mobilised and transported. Since the soil surface has the highest concentrations of P (Ahuja *et al.*, 1981; Sharpley, 1985; Culleton *et al.*, 2000), few binding sites are available for resorption. Potential to contribute diffuse losses of P only exists if a source area is hydrologically linked to a receiving surface water body (Heathwaite *et al.*, 2005), and therefore, not all land has an equal risk of contributing P to receiving waters.

Some soil can be regarded as hydrologically inactive with respect to surface overland flow, and fall into low risk soil types. These are typically permanent pasture with deep soils and high infiltration rates that are not prone to rapid fluctuations in water table level in response to rainfall. In these soils, most excess rainfall is drained through infiltration. As P-concentrations decline rapidly through the profile, the quantity of binding sites available for resorption increases with depth.

Implications for nutrient advice: the new P index

The results from these agronomic and environmental studies presented difficulties for the implementation of legislation for sustainable nutrient management.

The agronomic studies showed that the agronomic optimum Soil Test P (i.e. the soil P level at which maintenance fertiliser P applications ensure 95% of potential yield, and satisfactory herbage P concentrations), is approximately 6mg/l (Morgan's P-test). This soil P level was exactly at the breakpoint of the old indices 2 and 3. Were the old index 2, ranging from 3-6mg/l, to be adopted as the target index, this would mean that at low STP levels of 3mg, fertiliser P could only be applied at maintenance levels, which would raise serious concerns about herbage productivity and quality at the soil P levels. On the other hand, were the old index 3, ranging from 6-10mg/l, to be adopted as the target index, this could result in STP levels building up as high as 10mg/l, well above levels at which fertiliser applications yield economic returns.

The environmental studies demonstrated that risk of P-loss to water is related to STP levels, though the precise relationship may differ significantly across soil types. On poorly-drained soils, on which overland flow occurs regularly, STP levels of 8mg/l were reported to result in unacceptable levels of P-loss to water. By contrast, on well-drained soils, on which overland flow occurs only infrequently, no significant losses were reported at STP levels below 10mg/l. This would imply that the Target Index would need to account of soil drainage capacity. Choosing the old Index 3 as the Target Index would be environmentally sustainable on well-drained soils, but not on poorly-drained soils. The drainage capacity of individual soils can only be established by direct observation at field-scale, and the designation of individual fields to Target Indices would indeed have been very challenging to implement.

The new P index

Therefore, the old P-index system was revised to take account of these concerns. The new P-index for grassland (table 3) uses new breakpoints, based on the research projects described above.

Table 3. The new P Index for grassland

P Index	Soil Test P (mg/l, Morgan's)
1	0 – 3.0
2	3.1 – 5.0
3	5.1 – 8.0
4	> 8.0

In this new P-index, Index 3 (5.1-8.0mg/l) represents a Target Index that is both agronomically and environmentally sustainable for all soils. With an agronomically optimum STP of 6mg/l, maintenance rates are applied only to soils with STP levels between 5 and 8mg/l. As soon as the STP drops below 5mg/l, build-up P may be applied. At the same time, the new upper limit of Index 3 ensures that STP levels will not be built up in excess of 8mg/l. As a result, soil in the new Index 3 should not be significantly at risk of P loss to water, even on poorly-drained soils.

On peat soils, where the concept of building up P-reserves does not apply in practice, fertiliser should be applied at maintenance rates only to all soils with a STP of Index 1-3. On these soils, P should be applied in synchronisation with crop demand, i.e. little and often over the growing season.

On non-grassland soils such as with tillage crops, the P Index system has not changed. The "old" P Index (table 1) is still to be used for nutrient management for non-grassland crops.

Otherwise, the basis of fertiliser P advice for grassland has remained the same in the new P-advice, due to be published in early 2008, i.e. build up STP levels to the Target Index, apply maintenance rates only when the Target Index has been reached, and conduct frequent soil testing to ensure the soil remains at Target Index. In the new policy climate, the new P-index ensures synergy between agricultural production and the environment, by facilitating optimum productivity and herbage quality, while minimising risks of P-loss to water.

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Nitrates Regulations, Cross Compliance, and Derogations

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Introduction

The Nitrates Directive (91/676/EEC) was agreed by the member States of the EU in December 1991. This Directive requires that all member States protect water from pollution by nitrates from agricultural sources.

The EPA had been monitoring waters, which is a requirement of the Directive, and in 1996, Ireland published the 'Code of Good Agricultural Practice to Protect Waters from Pollution by Nitrates'. This was a voluntary code designed to promote sustainable farming practices while maintaining high water quality standards. It contained advice and recommendations on farm practices relating to: storage of organic fertilisers; standards and specifications for construction of storage facilities; when to apply organic and chemical fertilisers to land; the appropriate rates of application; and precautions to be taken to avoid causing water pollution.

Although the Code of Good Practice was in place, and being followed across the country a number of Ireland's bays and estuaries were found by EPA water monitoring to be either eutrophic or potentially eutrophic. On this basis Ireland were taken to court by the Commission and in March 2004, the European Court judged that Ireland was non-compliant with the Nitrates Directive and could be subject to fines. Ireland agreed a Nitrates Action Programme with the Commission in 2005. As part of this, SI 788 of 2005, a legally binding set of regulations that are designed to protect waters from pollution from agricultural sources was introduced. These regulations were signed in December 2005, and became effective on 1 February 2006. These have since been replaced by SI 378 of 2006. The Commission have accepted that Ireland is now compliant with the Directive and the threat of fines has been lifted.

Requirements of Nitrates Regulations

The requirements of the regulations can be summarised as follows:

1. Minimise the quantity of soiled water produced
2. Have adequate storage capacity for organic fertilisers, soiled water and silage effluent
3. Adhere to application limit of 170 kg/ha/yr of nitrogen from livestock manure
4. Fertilise to meet crop requirements
5. Do not apply fertilisers if conditions are unsuitable

6. Ensure all buffer zones are respected
7. Respect prohibited periods for spreading fertilisers
8. Follow rules about ploughing and applying non-selective herbicides
9. Keep required records as below

Required Records

1. Net area of holding
2. Crop areas
3. Livestock numbers and type
4. Estimate of annual fertiliser requirement (e.g. Nutrient Management Plan / REPS plan)
5. Results of any soil tests
6. Quantities and types of chemical fertilisers and organic fertilisers moved onto or off the holding
7. Description of facilities for the storage of livestock manure, soiled water, FYM, etc.,
8. Quantities of concentrate feeds fed to grazing livestock
9. Location of any water abstraction points on the farm
10. Records (e.g. concentrate feed used, chemical or organic fertiliser imports / exports) for any year must be completed by 31 March of the following year

Inspections

The Local Authorities are the competent authority for the Nitrates Regulations and are responsible for farm inspections.

Cross compliance

These Regulations are one of 19 SMRs plus GAEC that are inspected for during cross compliance inspections. 1% of applicants to the Single Payment Scheme are selected for inspection each year.

Cross compliance sanctions

Sanction may be imposed under cross compliance where breaches of the regulations are deemed to occur. The level of sanction will be determined as arsing due to either: (i) negligence; (ii) intent; or (iii) repetition.

Where non-compliance is due to negligence, the penalty will generally be 3% cut in the single farm payment, although the actual penalty could range from 0-5%, depending on seriousness of offence.

Where non-compliance is due to intent, the penalty will generally be 20%, with a range of 15-100% depending on seriousness. Penalties imposed due to offences that are deemed to be due top ‘intent’ maybe extended outside the year of the finding.

Where repetition of an offence occurs within 36 months, the penalty will be multiplied by 3, to a limit of 15%; after which the offence will be considered as an ‘intent’ breach.

Derogation farms

Since the stocking rate limit of 170 kg/ha of livestock manure N is below that of many grassland farms in Ireland, Ireland sought a derogation from the EU to allow grassland farms operate at higher stocking rates. This derogation was approved in November 2006. Farmers who wish to seek a derogation to farm at stocking rates up to 250 kg/ha livestock manure N can now do so by applying for, and adhering to the rules and requirements of, a derogation. In order to be eligible for a derogation, a minimum of 80% of the holding must be used for grassland cropping.

Requirements for a Derogation - 2008

Farmers need to decide now if they will need a derogation for 2008, allowing them to operate above the general limit of 170kg of livestock manure N to the hectare but not above 250kg. Farmers who intend to apply for a derogation must:

1. Have a fertilisation plan which meets the Department’s requirements prepared and available on the holding by 1st March,
2. Apply to the Department for a derogation.

Farmers will be able to apply for a derogation on their 2008 Single Payment application form. This means that the closing date for derogation applications in 2008 will be the same as the closing date for the Single Payment.

Farmers who need a derogation but are not applying for the Single Payment Scheme can get a separate derogation application form on the Department’s website or from the address below. The closing date for these applications will also be the same as the closing date for the Single Payment.

No applications for derogations will be accepted after the closing date.

Derogation terms and conditions and templates for fertilisation plans and fertiliser accounts can be found on the Department’s website at www.agriculture.gov.ie, via the link *Nitrates Information.* They can also be obtained from the Department of Agriculture, Fisheries and Food, Environment Section, Johnstown Castle Estate, Co Wexford (phone 053–9163400).

Further information

Further information on any aspect of the regulations is available through:

1. SI 378 of 2006
2. Explanatory Handbook for Good Agricultural Practice Regulations

3. These documents, along with other details, including materials relating to derogations and cross compliance, are available on the Department of Agriculture website: www.agriculture.gov.ie

Fertiliser Use Guidelines for REPS 4

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Introduction

The REPS scheme has been available to farmers since 1994, and since then, €2.3 billon has been expended.

When REPS 3 closed in October 2006 there were close to 60,000 participants and in that year €330m was paid out to farmers.

According to the Teagasc National Farm Survey, an estimated 48% of farms received REPS payments in 2006. The average family farm income (FFI) on those farms receiving REPS at €17,713 was 13% higher than FFI on non-REPS farms (Tables 1 and 2).

Table 1. FFI, Direct Payments on REPS farms by farm system - 2006

	Dairy	Dairy / Other	Cattle Rearing	Cattle Other	Sheep	Tillage	All
FFI	38546	20792	12655	13986	15066	26093	17713
Dir. Payments	23561	22001	17943	19722	20516	25015	20429
REPS Contrib.	6952	6162	5594	5384	6481	6866	6007
Farm Size (Ha)	44.9	41.1	32.5	32.7	37.7	46.7	36.6
Source: Teagasc National Farm Survey							

Table 2. FFI, Direct Payments on Non REPS farms by farming system - 2006

	Dairy	Dairy / Other	Cattle Rearing	Cattle Other	Sheep	Tillage	All
FFI	35145	27608	4867	8500	6647	30852	15744
Dir. Payments	16584	20949	7957	10589	8816	23434	12642
Farm Size (Ha)	44.3	53.8	23.7	26.8	7.1	65.5	34.5
Source: Teagasc National Farm Survey							

Over 76% of farms which participate in REPS are in the three dry-stock systems, namely Cattle Rearing, Cattle Other and Mainly Sheep. In previous REPS schemes the grassland nutrient levels allowed were constrained by an absolute limit of 170kgs organic N, a one for one limit of chemical N to organic N and an overall limit of 260 kg of N. In the case of tillage systems the limit of chemical Nitrogen allowed was capped at 80% crop requirement. This would have limited the entry of the more commercial dairy and tillage farms where the restriction in output together with the cost of compliance would not be sufficiently compensated for by the REPS payments contribution.

Objectives of REPS

REPS is an agri-environmental scheme and as such offers a blueprint to farmers for sustainable farming.

The objective is to promote the use of agricultural land for production and at the same time protect the environment having regard to, among other requirements, improving biodiversity, landscape and features, natural resources and water quality.

The scheme consists of eleven basic measures, each of which in their own prescription requires the farmer to have regard to appropriate nutrient management, water protection, creation of buffer zones, protection of features, training and keeping records.

There is a suite of biodiversity options from which each farmer in REPS is required to select from, the number and type of which is farm specific. They are designed to increase and enhance biodiversity on the farm.

There is also a selection of Supplementary Measures which are optional for the farmer but if selected from will further enhance biodiversity on the farm and increase payments for the farmer.

Nutrient Management

Measure 1 deals with nutrient management. This measure promotes the efficient use of nutrients appropriate to the type of farming being engaged in and the landscape in which the farm is situated. A REPS plan will therefore have organic and chemical recommendations that take on board the farming system, soil type, soil fertility, depth of soil, ground water quality, exposed waterbodies (rivers, streams and lakes) and sensitive habitats.

Nutrient Limits

The planner must first establish the baseline soil fertility of the farm with appropriate numbers of soil samples. In calculating the amount of Organic and Chemical nutrients used on the farm, the planner must refer to the European Communities (Good Agricultural Practice for Protection of Waters) Regulations 2006 (including any subsequent amendments to those regulations).

To calculate the amount of Nitrogen and Phosphorus from grazing and non-grazing livestock on the farm, the average livestock numbers planned for the farm must be established. Account must also be taken of any animal or other organic fertilisers imported or exported onto or from the farm.

Nitrates Directive and REPS

The Nitrates directive specifies a stocking rate limit of 170 kg Organic Nitrogen per ha for grassland farmers. Grassland farmers, with less than 20% tillage, who exceed this limit and who wish to continue farming at this intensity and below a limit of 250 kg Organic Nitrogen must apply for a derogation and make available a nutrient management plan each year.

The REPS scheme is now open to all farmers including those above the 170kg ON limit, providing they have applied for derogation. However the majority of farmers in REPS will be below the 170kg per ha limit.

The amounts of Chemical Nitrogen and Phosphorus which can be applied by a farmer over and above the nutrients supplied in the organic manure will be determined by the limits laid down by the Nitrates Directive and the rules governing the REPS scheme.

Nitrogen

Grassland

For non derogation farmers in REPS the planned stocking rate can not exceed 170 kgs Organic Nitrogen per ha. Based on this stocking rate and the estimated land potential, the planner must set down the Nitrogen requirement for grassland for each soil sample area. In any situation the maximum level of chemical Nitrogen which can be applied to grassland can never be greater than that produced from the planned stocking rate ie a one to one limit.

For derogation farmers the level of chemical nitrogen which can be applied, appropriate to the stocking rates between 170 and 250, is as set out in the nitrates directive document and allows a greater amount of chemical to organic nitrogen in specific situations. This situation will also apply to REPS farmers who have applied for derogation status.

It should be noted that in REPS there is extra payment through a supplementary measure to encourage farmers to incorporate clover into the sward to minimise the amount of chemical nitrogen to be purchased.

Tillage Crops

Tillage farmers in REPS 4 have two choices (table 3).

1. They can operate at 70% rate of crop requirement

   or

2. They can operate at 100% rate of crop requirement, as set out in the nitrates directive document, and undertake to set aside 6% of their arable area for land use under LINNET to a maximum of 2.4ha.

It is likely that more commercial tillage farmers will be interested in REPS 4 now that 100% of crop requirement is possible as against the 80% limit in previous REPS. Many of these farmers will have 2.4 ha of land not capable of giving an economic return to tillage but suited to LINNET.

Table 3. Maximum Fertilisation Rates of Nitrogen on Tillage Crops

Crop	Rate = 100% of crop requirement				Rate = 70% of crop requirement			
N Index	1	2	3	4	1	2	3	4
Winter Wheat	190	140	100	60	133	98	70	42
Spring Wheat	140	110	75	40	98	77	52.5	28
Winter Barley	160	135	100	60	112	94.5	70	42
Spring Barley	135	100	75	40	94.5	70	52.5	28
Winter Oats	145	120	85	45	101.5	84	59.5	31.5
Spring Oats	110	90	60	30	77	63	42	21
Sugar / Fodder Beet	195	155	120	80	136.5	108.5	84	56
Main-crop Potatoes	170	145	120	95	119	101.5	84	66.5
Early / Seed Potatoes	155	130	105	80	108.5	91	73.5	56
Maize	180	140	110	75	126	98	77	52.5
Field Peas / Beans	0	0	0	0	0	0	0	0
Oilseed Rape	225	180	160	140	157.5	126	112	98
Linseed	75	50	35	20	52.5	35	24.5	14
Swedes / Turnips	90	70	40	20	63	49	28	14
Kale	150	130	100	70	105	91	70	49
Forage Rape	130	120	110	90	91	84	77	63

Source; Department of Agriculture Forestry and Food

Phosphorus

Grassland

To provide optimum agronomic production, the desired soil index for phosphorus is Index 3. There are situations where it is desirable to maintain a lower soil phosphorus level. For example if the planner determines that the sample is from an area in which surface waters are at risk from phosphorus enrichment, he/she may advise a lower phosphorus requirement on that account. Such environmentally sensitive areas include designated SACs and NHAs where the agreed farming conditions indicate the maintenance of low soil phosphorus levels; plots which are steeply sloping towards a waterbody; peat soils; and areas of shallow limestone soils which are identified by the Geological Survey of Ireland as Areas of Extreme Vulnerability on Karst Limestone Aquifers. In these environmentally sensitive areas the phosphorus fertilisation rate must never exceed the maintenance levels for soil index 3 soils.

Based on grassland stocking rate and the environmental sensitivity of the farm the planner sets down the net chemical fertiliser requirement for each soil sample area. This is derived by taking the maximum phosphorus limits for grazing, hay or silage, shown in table 4, and reducing the level by 0.5 kg phosphorus for each 100kg of concentrate feedstuff used on the farm, and also the by the level of phosphorus present in the livestock manure produced over the winter.

Table 4. Maximum Phosphorus Limits for Grazing, Silage/Hay (kg/ha)

Soil Index	P Level Mineral Soils	Stocking rate (kg/ha Org N)	
		≤130	131 - 170
1	0-3 mg/l	35	39
2	3.1-5 mg/l	25	29
3	5.1-8 mg/l	15	19
4	> 8 mg/l	0	0

Adapted from Teagasc Nutrient and Trace Element Advice for Grassland, Tillage, Vegetable and Fruit Crops, 2nd. Edition, 2004 and SI 378 of 2006

Where the requirement for chemical phosphorus is small (10 Kg/ha or less), given the practical difficulty of spreading such light dressings, it is permissible to omit application in any one year and apply double the amount in the succeeding year, provided the same cropping obtains and the limits set out in Table 4 are not exceeded.

Tillage

The maximum amount of phosphorus applied to tillage crops must never exceed the limits set out in table 5.

Table 5. Maximum fertilisation rates of phosphorus on tillage crops

Crop	Phosphorus Index			
	0.0 -3.0 mg/l	3.1-6.0 mg/l	6.1 – 10.0 mg/l	>10.0 mg/l
	1	2	3	4
	Phosphorus (kg/ha)			
Winter Wheat	45	35	25	0
Spring Wheat	45	35	25	0
Winter Barley	45	35	25	0
Spring Barley	45	35	25	0
Oats (Winter & Spring)	45	35	25	0
Sugar Beet	70	55	40	20
Fodder Beet	70	55	40	20
Potatoes: Main crop	125	100	75	50
Potatoes: Early	125	115	100	50
Potatoes: Seed	125	115	100	85
Maize	70	50	40	0
Field Peas	40	25	20	0
Field Beans	50	40	20	0
Oil Seed Rape	35	30	20	0
Linseed	35	30	20	0
Swedes/Turnips	70	60	40	40
Kale	60	50	30	0
Forage Rape	40	30	20	0

Where organic manure is being applied to tillage crops the chemical Nitrogen and Phosphorus levels allowed under crop requirement must be reduced by the available levels in the manure being applied.

Conclusion

It is expected that the level of participation in REPS 4 will exceed that of previous REPS total of 60,000 and that the final total will be 70,000. To achieve this level the extra numbers will have to come mainly from the commercial dairy and tillage sectors. Recent increases in profitability at farm level in these sectors will reduce the attractiveness of REPS. The attraction for non derogation dairy farmers will be the annual minimum payment of over €8,000 for a farm of 40ha with higher levels of nutrients allowed than in previous REPS. For derogation farmers, there will be the added incentive that the nutrient management plan, which is a component of REPS, will double as a derogation nutrient management plan. Tillage farmers in REPS 4 who opt for the 100% rate of crop requirement will not be at any disadvantage as against non REPS tillage farmers. However, as REPS is an agri-environmental scheme there is a considerable degree of biodiversity commitments to be undertaken with consequential set aside of land involved together with associated costs of compliance.

Farmers currently in REPS and wishing to progress to REPS 4 will receive an increase in payment in the order of 17%. They can avail of the higher levels of nutrient inputs allowed if they so wish and increase output as a consequence.

Maximising the value of K and Mg fertilisers

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Introduction

Potassium (K) or 'potash' is an essential plant nutrient and for most crops, is required in greater quantities than either nitrogen or phosphorus. With the recent focus in Ireland on environmental protection legislation and how this affects Nitrogen and Phosphorus use there has been very little focus on the importance of K in the farming system. K remains a key driver of yield for grassland and tillage crops and has a myriad of benefits and functions in the plant for healthy crop growth. It is proposed here that K use in Ireland has declined to sub-optimal levels not least because of confusion reigning from the implementation of the nitrates directive and the new rules governing the permitted use of mineral fertilisers. If focus on K has been poor the focus on magnesium (Mg) has been worse still. Despite forever being incorrectly termed a trace element or micronutrient, magnesium requirements for many crops are similar to those for Phosphorus. This paper discusses the importance of both K and Mg in Irish agriculture and how the correct management of these nutrients can be optimised not only to promote healthier yields of crops but also to limit risk of nutrient imbalances in forage. It is also now of utmost importance that every kg of N and P are utilised efficiently and not lost to the environment. K and Mg fertilisers have a vital role to play in promoting and maintaining a balanced approach to fertilisation and improving the efficiency of all fertiliser applications to crops.

Why K and Mg ?

K and Mg are both present in the soil matrix and solution as the positively charged cations K^+ and Mg^{++}. These positively charged ions are held onto the weak negative charges present on particles of clay and organic matter and thus are effectively held in reserve in stronger soil types. Because of the similarities in electrical properties, an excess on one or the other can result in poor availability of the other. In many countries there are large areas of farmland with chalky soils which are saturated with calcium and the same problems with antagonism occur here where high Calcium levels mask the availability of other cationic nutrients (K, Mg, Na) to crops. By aiming to achieve a balance in the soil, nutrient supply to the crops can be optimised. Many authors have tried to quantify the ideal ratio for K:Mg in soils and although this is a very complex question and based on many biotic, chemical and physical properties of a given soil, a general range of around 0.5:1 and 6:1 K:Mg seems appropriate and anything outside of these ratios could be deemed to be at potential risk of imbalanced fertility and resulting in a reduced availability of one of these nutrients. It is often said that "Potash needs magnesium" and from the results of field trials where the two are applied at optimal levels certainly reinforce this concept.

Functions of potassium and magnesium

Potassium for assimilate building and transport, water balance and efficient N use

Potassium is present in the cell sap in relatively large quantities and it is the concentration of this solution relative to that of the soil solution, the air and the other plant tissues, that provides the basis for most of the functions of potash in a plant. Correct levels of K in the plant create an osmotic gradient to enable water and therefore nutrients to effectively enter the root system. Adequate K within the plant will then maintain water pressure and therefore structural stability. This role in water management is becoming increasingly more important globally as the changing climate gives us less predictable precipitation patterns coupled with an increasing pressure on irrigation water supplies.

K is also strongly linked with the transport of the products of photosynthesis to storage organs in the plant and therefore is vital for dry matter yield.

Lastly, potassium is also involved in many enzymatic reactions within plants and for these functions is largely irreplaceable.

Magnesium for formation of Chlorophyll, enzyme activation and protein formation

Magnesium is perhaps most commonly known as occupying the centre of the chlorophyll molecule and around 30% of all Mg present in a plant can be found within the chlorophyll.

Magnesium is also required for many other important processes in plants including protein synthesis, cell wall formation, osmotic balance and Mg is exceptional in activating more enzymes than any other mineral nutrient (Epstein and Bloom 2004). Mg also has a particularly strong interaction with potassium and nitrogen which are the principle drivers of yield but is also involved with the uptake, transport and metabolism of P.

Deficiency of K and Mg results in yield and quality losses

Plants deficient in Potassium may often not show obvious visible symptoms but are subjected to a range of stresses which all ultimately impact negatively on the potential yield of a given crop. Magnesium deficiency is generally easier to detect but yield penalties often occur well before physical deficiency symptoms in the field and the best advice is to maintain the adequate soil indices. Table 1, below summarises the main problems and symptoms associated with deficiency

Table 1. Effects of Potash and Magnesium deficiency on plants

Potash deficient plants	Magnesium deficient plants
Are more subject to lodging due to weaker straw / stem strength	Become deficient at below 0.2-0.3% Mg (as % dry matter)
Are less able to take up other nutrients including N and therefore may be severely stunted	Show classic yellow mottling between the leaf veins which themselves remain typically green (broad-leaved crops)
Often show necrosis around leaf margins	Eventually show white areas between veins which may then die
Are more subject to wilting in hot dry conditions	Display yellowish mottling on older leaves which can turn into necrotic spotting (cereals)
When overwintered, are more prone to frost damage and diseases	Older leaves are usually affected first due to mobilisation of Mg to the greatest point of need (younger leaves)
Often disappoint in terms of yield	Use N, K and particularly P inefficiently
Lack K for vital biochemical pathways will reduce the efficiency of the plant	Will not be able to photosynthesise efficiently and therefore often disappoint in terms of yield

Attitudes to K fertiliser in Ireland

There has always been a historical degree of confusion over P and K which are often lumped together as “base fertiliser” or “PK” fertilisers when in truth the only real connection is that they are both non-nitrogen fertilisers essential for plants in relatively large quantities. In Ireland which has an agricultural system based almost entirely on the use of NPK fertilisers and straight nitrogen it appears to be a common misconception that regulations restricting the use of one or more of the constituent nutrients affect the use of all fertilisers. It should be made clear that K does not present the same potential environmental problems as N and P. K applications are not currently subject to any restricted application periods. With fertiliser prices currently increasing rapidly and increasing legislative regulation governing the use of N and P fertiliser it appears that a farming system based on a series of basic grades has become too simplistic. The broad brush ‘one product does all’ approach is agronomically unsound and always has been except now there are additional financial and regulatory pressures concerning the use of nutrients on farms so that there needs to be a more targeted approach based on exactly what a field requires and applied at the most efficient timing/s rates and product choices. This needs to be based on regular soil analysis, needs to take account of organic manures and needs to be based on science and long-term economic responses. The use of NK products in particular has not been implemented to a great degree in Ireland and there are opportunities for these products where P is restricted or adequate

Despite the fact that sufficient K is absolutely vital to balance N (1:1 ideal) for high grass yields, many livestock farms are applying far too little K either due to poor knowledge about the penalties of insufficient K or because of fear of all manner of “side effects”. It is true that docks do flourish with adequate K but so does grass and deliberately keeping soil fertility at sub-optimal levels in order to suppress weeds is a highly questionable exercise. Far better to maintain adequate fertility, maximise productivity and invest in a robust herbicide regime to control the docks. The other fear is that of K causing staggers or grass tetany in cattle. It was thought in the 1960’s and 1970’s that “luxury uptake” of K occurred in grass where K levels were high and K fertilisation plans were planned to avoid such uptake. It is now known however that this elevated K status in spring is actually necessary for the plant to maintain turgor pressure (Johnston 2007) and without it, N response and yield are restricted (Milford and Johnston 2007). With careful planning of rates, timings and accompanying nutrients, the problem can be reduced or eliminated (see section on K, Mg and Na).

K application in Ireland

K has traditionally been applied as a component of a compound fertiliser most often in the form of one of the traditional NPK’s such as 18:6:12 or 10:10:20 and very seldom as a straight. Now that the use of N and P is restricted as a result of the implementation of the nitrates directive, if there is no change to the fertiliser policy then reduced N and P will mean reduced K applications which could potentially impact K usage rates below that for optimum yield and lead to a national decline in soil fertility at a time when there should be a renewed focus on maximising yield. K and Mg can therefore be autumn applied and in fact for medium or heavy soil types this is the best timing from an agronomic view so that the nutrient can be thoroughly mixed with the upper soil layers before cropping. The following figure shows the percentage of K applied in the autumn in the UK where these traditional autumn applications are returning to popularity in order to spread workload, give more flexibility for precision farming and flexibility in choice of nitrogen product.

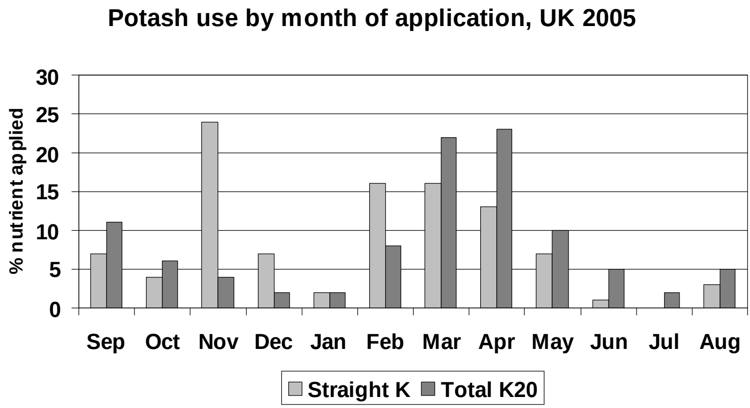

Figure 1. Potash use by month of application (from British survey of fertiliser practice 2006)

Declining K use in Ireland increases the likelihood of inefficient N use and reduced soil fertility

Despite increases in yields/ha for most crop groups in Ireland in the past decade, the quantity of K applied has reduced dramatically and soils are being effectively mined of potash. Although it may take several years for exchangeable K to be mined to below optimum level, it can also take a long time and significant very large dressings to build soil K up again. The best advice is to fertilise for target index and then replace offtake making an adjustment for organic manures applied. K depletion will occur on most soils if offtake exceeds inputs.

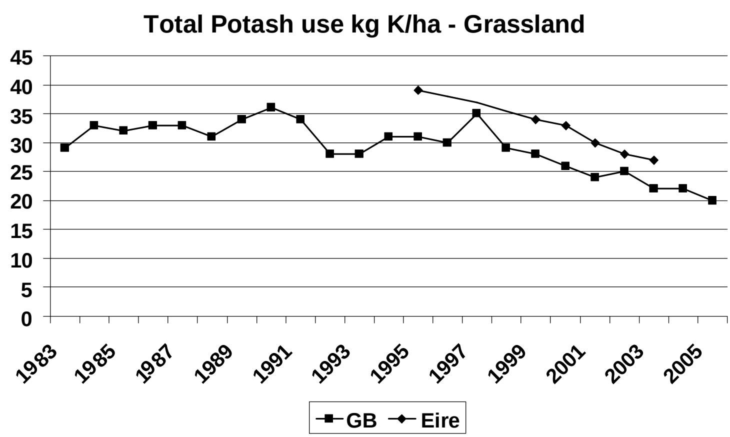

Figure 2. Declining K use on grassland (GB data – British Survey of Fertiliser Practice 2005; Eire data – Teagasc fertiliser use survey, Coulter et al)

K fertilisers and value for money

At the time of writing this article, the cost of Potassium and Nitrogen fertilisers are increasing at an alarming rate due to global demand and in recent months, P prices have also seen unprecedented price rises. It appears that the 400 euro/tonne for NPK's is now a real prospect in the near future. With these new prices, it is important to re-assess the cost efficiency of using fertilisers in the light of the current climate with commodity prices for crops also at record highs. From research based on classic K experiments at Rothamsted and more recent studies by K+S KALI GmbH, Armstrong-Fisher and the PDA (Potash Development Association) looking at responses to K and Mg on K or Mg depleted soils it is possible to attempt an approximate potential cost-effectiveness calculation for each crop. Many of the experiments below were conducted at very low nutrient status but the yield responses are a useful reminder of the big potential penalties of letting soil K and Mg levels slip.

Table 2. Yield and economic benefits from experiments with K and Mg fertiliser applications

Researcher	crop	No. of trials	Soil K/Mg	Yield increase	Value of nutrient applied at current prices	Value of increased yield at current prices/ha	Cost efficiency for each euro spent
Potassium experiments							
PDA (87-90) UK	Silage grass	1 long term	Index 1 (UK)	Yr 1 12% Yr 2 32% Yr 3 49% Yr 4 87%	€112 each yr/ha	High!	N/D
PDA (97-90) UK	Winter wheat	1 long term	Index 1 (UK)	Yr 1 0 Yr 2 0.5 t/ha Yr 3 4.1 t/ha Yr 4 3.6 t/ha	€49 each yr/ha	€1886	X9.6
Rothamsted (57-58)	Potato	1	112 ppm	9.1 t/ha	€83	€1820	X22
Magnesium experiments							
Armstrong-Fisher (05-07)	Potato	6	Index 0-1 (UK)	3.1 t/ha	€14	€96	X6.8
Armstrong-Fisher (04-07)	OSR	8	Index 0-1 (UK)	0.24 t/ha	€90	€585	X6.5
Armstrong-Fisher (04-07)	Beet	7	Index 0-1 (UK)	3.3 t/ha	€90	€110	X1.2

As a general rule of thumb there is up to 10 euros return for each euro spent on K on very depleted soils, up to 5 euros for soils low in K and if K fertiliser is omitted on adequate soils for a number of years, it will fall into a lower index where financial penalties will hit.

K for efficient N use

Deficiency of any nutrient can reduce crop yield and uptake of other nutrients. This is especially so for the relationship between potassium and nitrogen. A deficiency of potassium can affect nitrogen uptake and transport from roots to shoots, protein development and yield in a crop. Potassium is an activator for some forty enzymes, and is involved in the development of proteins from nitrate that has been taken up. Inadequate potassium leads to an accumulation of nitrate in the roots and this can restrict uptake of more nitrogen from the soil. There will be a consequent effect on the efficiency of utilisation of nitrogen applied in fertilisers or manures. Poor efficiency of nitrogen utilisation will lead to unnecessary nitrogen residues in the soil and to an increased risk of nitrate leaching not to mention a waste of valuable fertiliser.

In a recent experiment in a cereal crop in Germany, the efficiency of N uptake was investigated with varying rates of K, K+Mg and K+Mg+S to demonstrate the penalty of applying N without sufficient accompanying nutrients

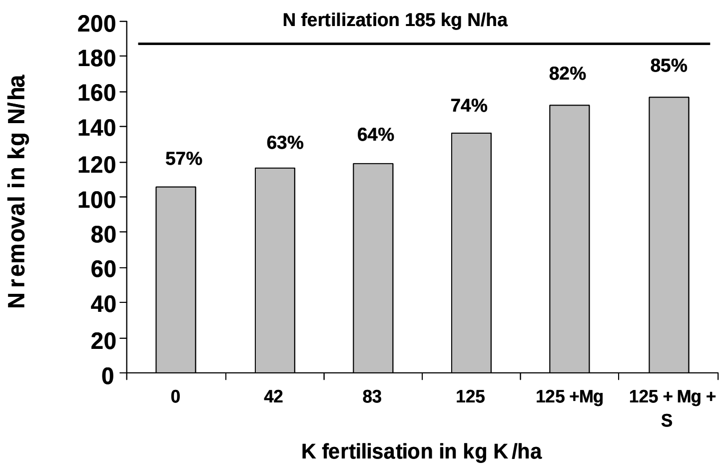

Figure 3. Effect of K fertiliser on N efficiency

Crop K and Mg requirements

Requirements for these nutrients is based more on cost-effectiveness than restrictive environmental based guidelines and in most countries, a target soil level is proposed for each crop type based on economic returns for the farmer in a rotation and not from a single crop. The basis then for K and Mg applications is to maintain this target level by replacing nutrient removed in cropping, through inevitable field losses and from movement of nutrient into deeper horizons or that which is fixed into the reserve pool.

On heavier soils which can often effectively "hold" K and Mg, applications can be made on a semi-rotational or a rotational basis where the largest applications are applied before the most responsive crop with the idea that the nutrient will be well supplied to the responsive crop, (particularly those with a poor root structure such as potatoes) and then sufficient K or Mg will remain for the next crop/s in the rotation.

The guide below is a comparison of the recommendation for a series of EU countries based on application to soils of a moderate or 'target' K level (Index 3 in Ireland). All figures have been standardised to elemental K for ease of comparison to Ireland.

Table 3. Comparison of K recommendations in a range of EU countries

	Winter cereals (straw baled)	Winter oilseed rape	Silage grass	Potatoes	Spring barley (straw baled)
UK	58-79	17-33	166-266	228-249	46-66
Ireland*	60	25	190	185	60
France	106	28	174	351	38
Germany	75-125	116-166	141-199	116-249	50-108
Netherlands	75-125	116-166	240-315	116-249	50-108

(Ristimaki, 2007)
* (Coulter et al 2001)

Although interesting, the figures cannot be directly compared because of the differences in the rotational policies between countries. This also highlights another interesting point, that of the difference between offtake and uptake. For example the German K recommendation for OSR appears high in comparison to the UK and Ireland but it is recognised there that although OSR does not remove vast quantities of K (offtake) the crop does take-up large quantities during growth (uptake) much of which is returned to the soil when the crop dies back or when harvested parts are returned. A German farmer growing a cereal after 120 kg or greater application to

OSR may well reduce or even omit K as he will deem the application to the previous crop to have left sufficient K in the field. Yield aspirations also vary between countries

Nutrient content of crops

Most base nutrient programs are based around replacing nutrients removed with cropping and thus it is essential to have reliable offtake data per tonne for all agricultural crops. In this way, specific recommendations can be made based on realistic yield aspirations and more accurate adjustments can be made according to the fate of crop residues. The figures below are again adjusted into elemental nutrient for consideration in Ireland

Table 4. K offtake in crops

Crop	Kg K/tonne fresh material*	kg Mg/tonne fresh material**
Grain only (all cereals)	4.6	1.2
Grain + Straw (WW/WB)	9.8	1.9-2
Grain + Straw (SW/SB)	11.4	
Grain + Straw (oats)	14.4	
OSR (seed only)	9.1	3.4
OSR (seed + straw)	14.5	-
Peas – dried	8.3	1.8
Peas – vining	2.7	-
Field beans	10	1.4
Potatoes	4.8	0.21
Sugar beet- roots only	1.4	0.3
Sugar beet – roots and tops	6.2	1
Fresh grass (15-20% DM)	4	-
Silage (25% DM)	5	0.3
Silage (30% DM)	6	-
Hay (86% DM)	15	-
Kale	4.2	0.3
Maize silage (30% DM)	3.7	0.7
Swedes – roots only	2	-
*(RB209 – DEFRA 2000) ** (FACTS nutrient reviews 2006)		

Potassium for grass production

Grass silage is the single most important source of winter feed on Irish farms with almost 25 million tonnes ensiled annually (Murphy 2003). With cereal prices now at record highs and looking to continue to be strong the incentive for maximising the value and quality of home grown grass in Ireland to reduce costs and increase self-sufficiency has never been as great. In order to achieve the potential yields that modern ryegrasses have been bred to attain the fields need to be highly fertile and care should be taken to replace those nutrients removed through silage-making. In an investigative study conducted for IFI farmer clients who had reported poor N responses in silage fields, almost all had inadequate K reserves and between 1996 and 2001, the usage of K fertilizer declined by 31% in Ireland (Murphy 2003) In 2000, Teagasc considered 63% of multi-cut silage fields to be low or deficient in K and similar results were reported by Murphy, (2003) who reported that 71% of two-cut fields were below the target index for K and therefore were at risk of underperformance and poor nitrogen use efficiency. The same study looked at how slurry applications decreased alarmingly with increasing distance from the pit and although this study was pre nitrates directive, it still highlights the poor redistribution of K on many farms

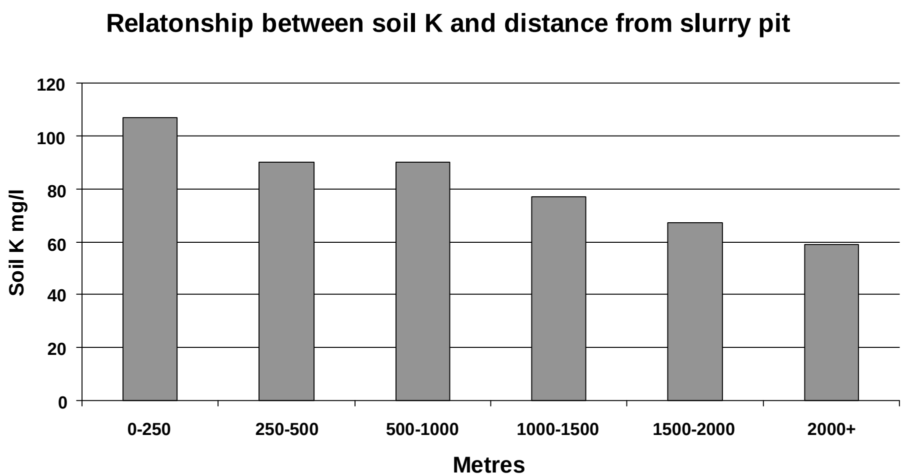

Figure 4. Relationship between soil K and distance from the slurry pit

Product choice

There have never been as much choice of fertiliser materials as today and many blenders will offer a bespoke service which can be tailored to the individual farm, crop, field and even field section through the use of precision application equipment linked to GPS data from detailed soil sampling. Different forms of the nutrients can have very different properties and it is important to appreciate the key differences, advantages and disadvantages of each.

Sources of Potassium

Potassium fertilisers are available in different chemical forms each with different properties and the table below outlines the major sources together with specific advantages and usage implications.

Table 5. Sources of K fertiliser

Potassium Source	Common name	Accompanying nutrient	Uses	Advantages	Disadvantages
Potassium chloride	Muriate of potash (MOP)	Chlorine	All chloride tolerant crops (grass, cereals, beet, OSR, Maize)	Lowest cost per kg of K. Widely available	May cause damage to susceptible species particularly at sensitive growth stages
Potassium sulphate	Sulphate of potash (SOP)	Sulphur	All chloride sensitive crops or crops requiring additional sulphur	Low chloride for quality in cash crops. Widely available	Higher cost per kg K
Potassium nitrate	Nitrate of potash	Nitrogen	Very high value crops only (due to cost)	Fast acting foliar form for rapid uptake	Very high cost per kg K
Potassium phosphate / phosphite	N/A	Phosphorus	Very high value crops only (due to cost)	May have some activity against plant diseases	Very high cost

There has always been lots of debate around the use of MOP or SOP, particularly for crops such as potatoes. The following gives a summary of the effects of both on this crop

Table 6. Effect of fertiliser source on potatoes

	MOP	**SOP**
% Dry matter (flouriness)	▬	▲
Reducing sugars	▼	▼▼
Fat absorption on frying	▬	▼
Yield	▲▲	▲▲▲
Tuber size	▲▲	▼
Tuber number	▬	▲
After-cooking blackening	▼	▼▼
Internal blackspot	▼	▼
Taste	▲	▲▲
Maturation	later	Slightly earlier
Suitable for application “down the spout” at planting	No	Yes
Suitable for late application (within 8 weeks of planting)	No	Yes
Suitable for top dressing	No	Yes

The effects of SOP are primarily due to the lower chloride levels in this material. Chloride is known to reduce and inhibit transport of carbohydrates and thus when SOP is used as a K source, the movement of sugars produced by the haulm down to the tuber for conversion into starch can proceed more efficiently hence the higher dry matter and higher overall yield. Chloride is also a potential antagonist to the nitrate ion (NO3-) and thus in high quantities may restrict the availability of N to the plant.

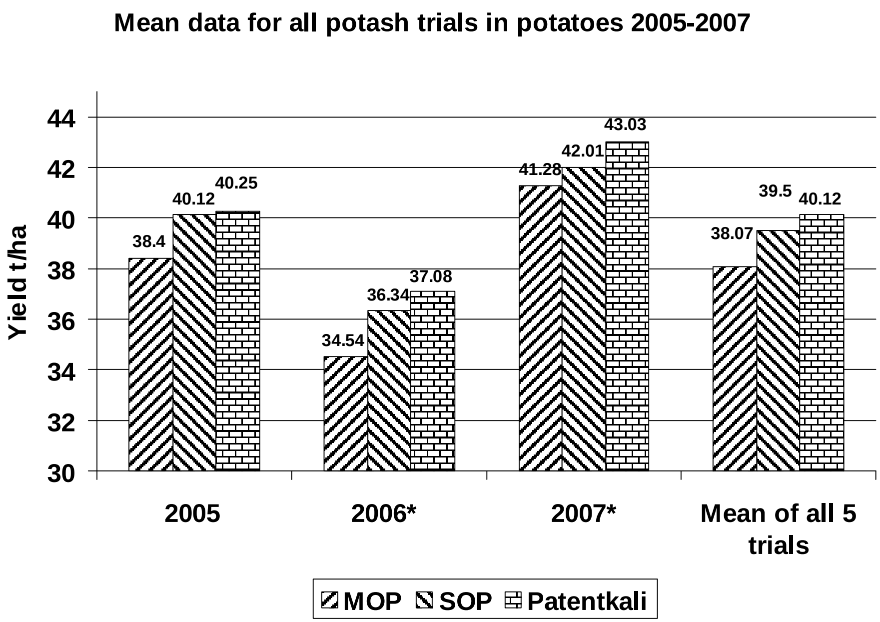

Figure 5. Mean data for all potash trials in potatoes (Armstrong-Fisher 2005-2007)

Sources of magnesium

Magnesium sulphate has the advantage that it is water soluble and is therefore unaffected by soil pH. Recovery values after 1 year have been reported to be around 80-100% (Heming and Hollis 1995) and yield of container grown maize was increased by over 10% when kieserite was compared to Mg Oxide even on a highly acid soil type (Hardter et al. 2004). Kieserite therefore appears to be a very suitable source of available magnesium for all soil types and under all conditions. Kieserite also has the advantage of containing a high level of sulphur to help to satisfy crop requirements.

Draycott and Durrant (1972) reported that Mg availability on neutral or alkaline soils from calcined magnesite was nil and that only on acid soils would any Mg be released. Since then, field experiments have consistently shown calcined magnesite to be less effective than Kieserite on a range of soil types and crops but particularly on neutral or high pH soils. Sher (2002) reported that Mg availability from Mg Oxide was up to 62 times less than that of Kieserite and Heming and Hollis (1995) showed that availability of even finely ground oxide material in acid conditions was significantly less than that of Kieserite. The same authors showed that recovery of Mg from coarser material on an alkaline soil was only around 10-20% after one year compared to around 80-90% from Kieserite.

Table 7. Sources of Mg fertiliser

Magnesium Source	**Common name**	**Uses**	**Advantages**	**Disadvantages**
Magnesium oxide	Calcined Magnesite (Cal-Mag)	Long term addition of Mg to acidic land	None	Not water-soluble so restricted to low pH sites. % recovery by crop is poor
Magnesium Sulphate	Kieserite ‘gran’	All crops on all soils regardless of pH	Water-soluble. Spreadable (36m) source of S (20% S)	
Calcium Magnesium carbonate	Dolomite / Mag-lime / Magnesian limestone	All crops where long term build up of Mg is required **and** where a need for liming is recognised	Relatively inexpensive per kg Mg	Mg only slowly available. May lead to excess Mg in very long term
Hepta-hydrated Magnesium sulphate	Epsom salt / Bittersalz (eg. EPSO Top)	Foliar application to prevent and alleviate Mg deficiency in growing crops or to provide a soluble Mg source for fertigation	High solubility and purity. Ease of use and direct uptake regardless of soil conditions	Can’t be tank mixed with calcium containing products
Magnesium Nitrate	-	Only for very high value cash crops due to cost	Contains N	Cost
Magnesium EDTA	Chelated magnesium	For foliar treatment of growing crops	Ease of use	Costs, very low Mg application/ha

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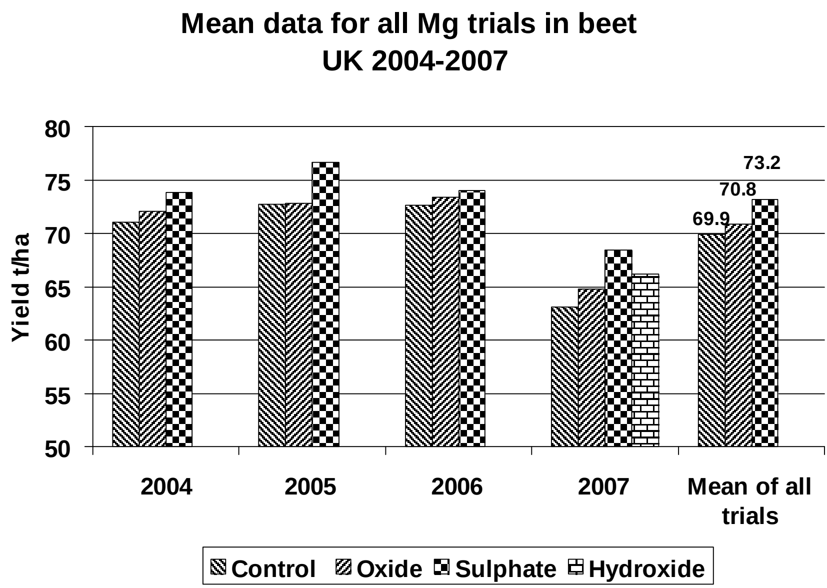

Figure 5. Mean yield data for Mg trials in beet (Armstrong-Fisher 2004-2007)

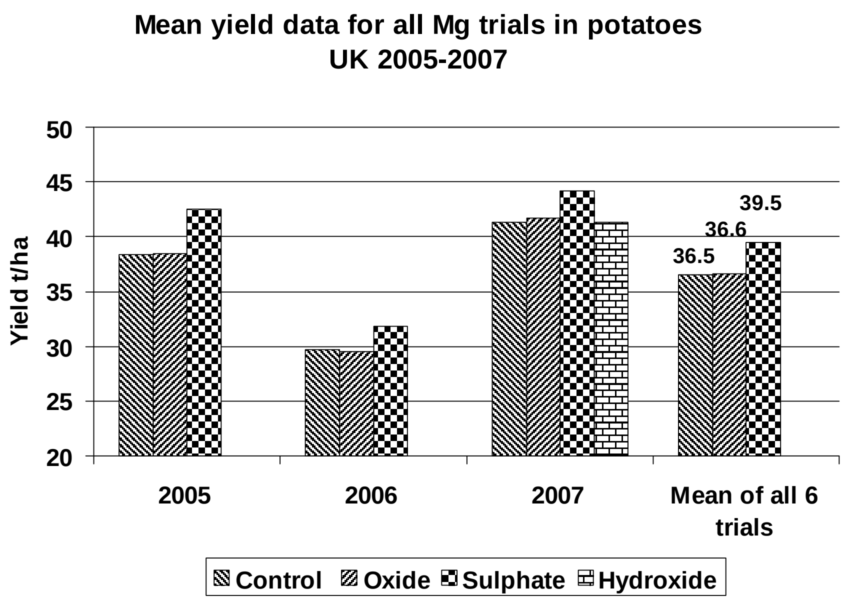

Figure 7. Mean yield data for Mg trials on potatoes (Armstrong-Fisher 2005-2007)

SOP with a very low salt index

Salt index of a fertiliser is a measure of the concentration and osmotic power of a substance. High salt indices particularly in intensive cropping situations can damage the roots of sensitive species. SOP has a salt index of 46.3 cf. MOP which has an index of 116.6. This makes SOP particularly suitable for application to covered crops or where fertilisers are band placed close to the roots / seed

Fertiliser product choices

Apart from the use of straight K fertilisers MOP or SOP there are not too many products on the world market. In many other European countries such as Germany, France and increasingly in the UK, potash is applied as a mixture with magnesium in a ratio designed to maximise availability of both nutrients and also to match the crop requirements for these nutrients and therefore maintain adequate soil fertility. Such products also benefit from containing sulphur since the magnesium source is Kieserite (Magnesium sulphate)

Korn-Kali is such a product which is widely used throughout Germany in particular. It is a complex compound fertiliser (CCF) which has a ratio of K:Mg designed to match the requirements of grass, combinable crops and many root crops and contains enough sulphur to meet most or all of the S requirement depending on application rate

Patentkali is a similar product although uses SOP as a source of K and also includes a higher quantity of magnesium and sulphur. For these reasons, patentkali is more suited to potato, vegetable and fruit production or for special crops such as forestry or floriculture.

Table 8. Nutrient contents and spreading restrictions of common sources of K and Mg

Product	**N%**	**P%**	**K%**	**S%**	**Mg %**	**Na %**	**Restricted spreading times**
After-cut NK	16-20	-	14-16	0-2	0-2	-	Approx Sept-Jan*
PK	-	7-10	20-30	-	-	-	Approx Sept-Jan*
MOP	-	-	50	-	-	-	NONE
SOP	-	-	42	18	-	-	NONE
Korn-Kali	-	-	33	4	3	3	NONE
Patentkali	-	-	25	17	6	-	NONE
Magnesia-Kainit	-	-	9	4	3	20	NONE
* Exact dates vary according to area							

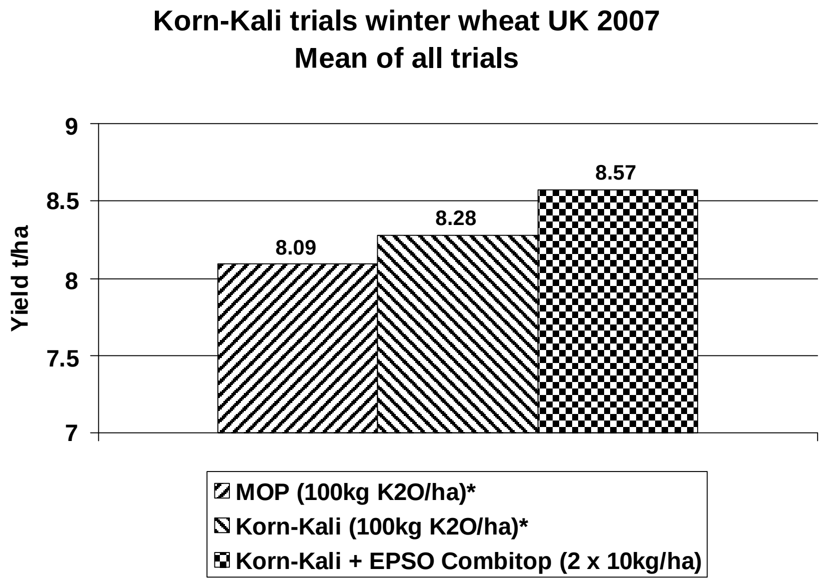

Figure 8. Mean yield data from trials using Korn-Kali on winter wheat (Armstrong-Fisher 2007)

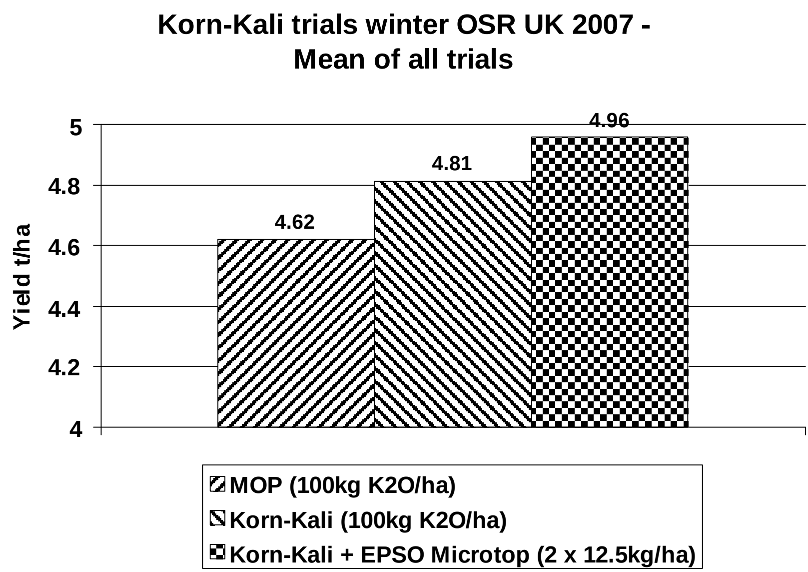

Figure 9. Mean yield data from trials comparing K fertiliser types on winter OSR (Armstrong-Fisher 2007)

Potassium in organic manures

The potassium present in manures can make a valuable contribution to the farm requirements and around 90% of the K is thought to be either available or potentially available (DEFRA, 2000).

Limitations of K supplied by manures

The quantity of slurry required to supply all of the K to a productive silage ley would be prohibited due to the high relative proportion of N and P contained in most slurries and it must be remembered that K from manures can only recycle K already in the system. Applying little or no K and relying on slurry applications alone will deplete soil K over time as losses occur to groundwater, to lower soil horizons or through exportation from the farm in milk, meat or produce.

Potassium supply is often in short supply on organic farms. Whilst reasonable levels of N and P can be obtained with use of animal manures, these materials are inherently low in Potassium and if high yields are expected then supplementation is required unless on land which is naturally rich in K releasing clays. Under EU Directive 2092/91 the following sources of K may be used:

1. SOP from physically extracted sources
2. Patentkali
3. Magnesia-Kainit
4. Kali-Vinasse
5. Feldspars and other insoluble K containing rocks

All of these products are also now certified by the UK Soil Association

Potassium in soils

There is much talk around the subject of nutrient fixation in soils. Firstly it is useful to try to define fixation since the term is used in two very different ways

Firstly, fixation is sometimes used to describe the process of a soil effectively being able to “hold” a nutrient within the structure of the soil which is then available for plant uptake as and when the root system absorbs nutrient in soil solution. The type of soils which are best able to effectively “hold” cationic nutrients are those with a high Cationic Exchange Capacity or CEC. Factors which affect the CEC include clay level and type, organic matter level, soil structure, biological activity and presence of calcium in particular. Generally speaking, for mineral soils, the richer in clay and the presence of reasonable quantities of organic matter (>5%) the higher the CEC and the higher the buffering capacity of the soil. In these soils, very large quantities of nutrient can be stored for long periods and often the application of fertiliser has very little bearing on the exchangeable K level. Conversely coarse sandy soils with free drainage and poor levels of organic matter (<5%) have the least ability to hold nutrient

The term ‘Fixation’ is also often used to describe the process of a soil effectively binding (or “locking-up”) a nutrient into a structure of the soil which then is rendered unobtainable and which then is only available very slowly by the natural weathering processes which occur in soils. In these cases the advice is similar to that for sandy soils. Frequent small dressings should be made close to the point of need (spatially and temporally) and no attempt should be made to significantly raise the K index.

There is evidence that such soils exist in some Irish counties and monitoring of exchangeable soil K after application of K fertiliser would be the surest method of determining whether a clay soil has these properties.

The principle of manuring is to keep these soils above the critical minimum value relevant to the crops grown. In practice because soil nutrient levels cannot be raised and lowered over short periods, the appropriate status will be that for the most demanding crop grown in the rotation. Fertiliser policy should then maintain this level by replacing the nutrients removed by the rotation. For lighter soils applications must be annual or even split within the season. On medium or heavier soils rotational manuring may be followed, applying 2 or 3 years requirement before the most responsive crop e.g. roots, legumes etc. Annual applications are normally advisable where grass is cut to avoid possible luxury uptake.

Potassium, Magnesium, Sodium and animal nutrition

Productive grass fields take up a large quantity of potash and when fertilised intensively with N, the grass dry matter should contain 2.5% K. Less than this would indicate an insufficient supply of available soil K and the response to N would suffer. In the spring with a plentiful nutrient supply growth can be very rapid and it is under these conditions when very much higher levels of K can accumulate in the foliage to maintain turgor and yield potential. This high K content can, if Mg and Na contents are also low, result in the condition hypomagnesaemia or more commonly grass tetany or staggers may occur. This condition has often been connected with a poor supply of Mg and hence extra supplements are given frequently in licks, in boluses, by injection or in drinking water to raise blood Mg in the animal. However, supplying extra Mg is not the one-stop solution and the role of sodium and the balance with K and Mg is of vital importance.

Supplementation of cattle diets with Na and Mg usually relies on concentrates, mineral compounds, salt blocks and Mg added to drinking water. Self administered, free-access techniques are not ideal because intake in dependent n individual tastes and not always on requirement. These methods undoubtedly have a role in maintaining stock health but the consistent production of balanced herbage is a great starting point for long term health and to help to prevent the need for acute supplements to improve ailing health and condition

On farms where staggers is a recurring problem, attention should be given to the potassium, magnesium and sodium content of herbage. Normal magnesium concentrations in herbage are frequently below the minimum 0.20% suggested for animal diets. Magnesium % in plants is affected by a large number of factors and whilst the risks of magnesium disorders may increase with lower herbage magnesium, this is not a reliable measure of whether clinical mineral problems will occur in the animal.

The level of sodium should also be considered. Where herbage sodium levels are above the minimum dietary guide of 0.15% Na, the risk of staggers is low, but rises with lower sodium levels.

Much of the sodium consumed by cattle and sheep is used in the production of saliva which is secreted into the rumen to maintain a constant pH by neutralising acids formed by bacteria in the rumen liquor. If the sodium content of forage is too low, the animal automatically substitutes potassium for sodium as an alternative buffer in the saliva and diverts sodium to maintain blood Na level as first priority.

The resulting increase in K:Na ratio in the rumen leads to reduced resorption of Mg through the rumen wall into the blood - hence placing the animal at risk to hypomagnesaemia. However, it is only in extreme cases that a low blood level of magnesium occurs (less than 1.8mg/100ml of blood in cows) and the consequences of the condition (reduced milk yield and even death) may arise without ever detecting low blood Mg.

Nutrient balance is important in avoiding mineral disorders and experimental work has shown that there is less risk of staggers when potassium, magnesium and sodium levels in herbage result in K:Na and K:Mg ratios of between 10 and 20:1 and a greater risk of staggers at K:Na ratios greater than 20:1 together with too low Mg content in the grass DM (>0.15% Mg). Field trials and surveys have shown that maintaining a high level of sodium and magnesium in grass will reduce the risk of staggers (PDA, 2005)

The following table gives a useful guide to the required K, Mg and Na balances in forage

Table 9. Required K, Mg, and Na balance in forage (PDA).

Potassium	Magnesium	Sodium
Over 3% - high review timing and quantity check K:Na & K:Mg ratio Below 1.75% - low check amount of K applied review manuring policy	Under 0.2% - low consider magnesium application K:Mg over 20:1 - too wide reduce ratio (usually by applying magnesium with a highly available Mg source)	Under 0.15% - low consider applying sodium 0.15 - 0.5% added benefits to palatability K:Na over 20:1 - too wide reduce ratio (usually by applying sodium)

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