Moorepark Dairy Research Update

A Guide to Management of White Clover in Grassland

James Humphreys and Aidan Lawless, Teagasc

Moorepark Dairy Production Research Centre

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Moorepark Dairy Production Research Centre
Teagasc
Moorepark
Fermoy
Co. Cork

Tel: 025 42222
www.teagasc.ie

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MOOREPARK DAIRY RESEARCH UPDATE

A GUIDE TO MANAGEMENT OF WHITE CLOVER IN GRASSLAND

Authors

James Humphreys and Aidan Lawless, Teagasc, Moorepark Dairy Production Research Centre

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Authors James Humphreys and Aidan Lawless, Teagasc, Moorepark Dairy Production Research Centre.

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1. Role of White Clover and Irish Grassland

White clover has a number of useful attributes. *Rhizobia* bacteria live in nodules on the roots of white clover and have the capacity to make N available in the soil for pasture production. The quantity of N supplied can be as much as 120 units per acre (150 kg/ha). When managed in the right way this N can make a considerable contribution to farm profitability.

At present, the rising cost of oil internationally is driving up the cost of fertilizer N. At the same time, changes to the Common Agricultural Policy following the Luxemburg Agreement have resulted in the decoupling of direct payments from production and declining milk price. This has radically shifted the relationship between the cost of fertilizer N inputs relative to net income and profit accruing directly from sales of produce from the farm.

White clover has very high digestibility. In fact, it has the highest digestibility of any grassland species including perennial ryegrass. It is often difficult to maintain the digestibility of grass-only swards receiving low inputs of fertilizer N. White clover can generate its own supply of N and thrives under low fertilizer N input; the less fertilizer N that is applied the higher will be the clover content of the sward. Higher clover contents result in swards with higher digestibility.

Six years research at Solohead has shown that well managed grassland with a moderate clover content (20 to 25% on an annual basis) and receiving annual fertilizer N inputs of around 70 units per acre (90 kg/ha) have a carrying capacity of 0.8 cows per acre (2.0 cows/ha) producing 1400 gallons milk per cow (6400 kg/cow) or over 1100 gallons per acre (13.0 t/ha).

Average fertilizer N use on Irish grassland is around 70 units per acre (90 kg/ha). Obviously there is a lot of variation from farm to farm and over 300 units per acre (375 kg/ha) being used on some farms, or at least, on some parts of some farms. There are also differences between farming systems with generally higher rates of fertilizer N being used on dairy farms compared with beef or sheep farms. Average fertilizer N use on dairy farms is around 140 units per acre (170 kg/ha) and around 48 units per acre (60 kg/ha) on beef and sheep farms.

Table 1. Stocking rates and fertilizer N use on Irish grassland farms

Stocking rate (kg/ha of organic N)'	No. farmers ('000's)	Average fertilizer N use (units/acre)	(kg/ha)
< 100	85	<80	<100
100 – 170	33	80 – 150	100 – 185
>170	8	>150	>185

'one dairy cow = 85 kg/ha, one suckler cow = 65 kg/ha, one weanling + yearling = 81 kg/ha etc.

The vast majority (85,000) of Irish grassland farms are stocked at <100 kg/ha of organic N (Table 1). Fertilizer N use on these farms is quite low and, hence, the economic incentive to introduce clove r onto these farms is relatively low. The main reason for introducing white clover onto these extensive farms is to improve sward quality. Some lowering of fertilizer N costs is an additional bonus.

Around 33,000 farmers are stocked at between 100 and 170 kg/ha of organic N. Average fertilizer N use on these farms is between 80 and 150 units per acre (100 to 185 kg/ha). Substantial savings in fertilizer N can be made on these farms by adopting white clover. Indeed, the fertilizer N use on these farms can be halved. Many of the farmers within this category are eligible to join the Rura l E n v ironmental Protection Scheme (REPS) but have avoided doing so because of difficulties in complying with the rates of N fertilization allowed and because of the impact that cutting back on fertilizer N has on sward quality. Adopting white clover allows these farmers to benefit from REPS payments as well as the savings in Fertilizer N. Furthermore, in grass-clover swards, digestibility will increase rather than diminish under lower fertilizer N input.

A minority (8,000) of Irish gra s sland farms are stocked at >170 kg/ha of organic N (Table 1). The vast majority of these are dairy farms; with less than 200 being beef and sheep farms. These farms are highly reliant on high inputs of fertilizer N. For the most part it is not recommended that white clover is adopted on these farms; the stocking rate is higher than what can conveniently be carried by white clover-based pasture s. Some of these farms are fra g m e n t e d with grassland on outside farms being used with far less intensity than grassland near the milking shed. In such instances clover may have a role to play on the outside farms.

For example, a farmer with 140 acres (57 ha) and stocked at 0.95 LU per acre (2.35 LU/ha) and using annual fertilizer N inputs of 205 units per acre (254 kg/ha). By putting half of the farm under clover and low fertilizer N input (70 units/acre; 90 kg/ha) and the other half under grass-only swards receiving high inputs of fertilizer N (230 units/acre; 285 kg/ha) ove rall fertilizer N input can be lowered by around 30%.

The objective of this handbook is to provide a detailed farmerfo c used account of va r i o us aspects of white clover in gra s sl a n d , which include:

(i) The biological basis underpinning productivity;
(ii) Productivity and nutritive value of grass-clover swards;
(iii) Methods of increasing the white clover content of swards;
(iv) General management guidelines.

2. Clover growth and survival in grassland

2.1 Nitrogen fixation

The most extra o rdinary aspect of white clover is that it forms a mutually beneficial or symbiotic re l a t io nship with bacteria known as *Rhizobia*. These bacteria live in miniscule nodules on the roots of white clover (Plate 1). Not only does the clover provide a home for these bacteria it also supplies them with carbohydrates and other re s o u rc e s. Research has shown that up to 24% of clove r photosynthetic assimilates can be fed to the *Rhizobia*.

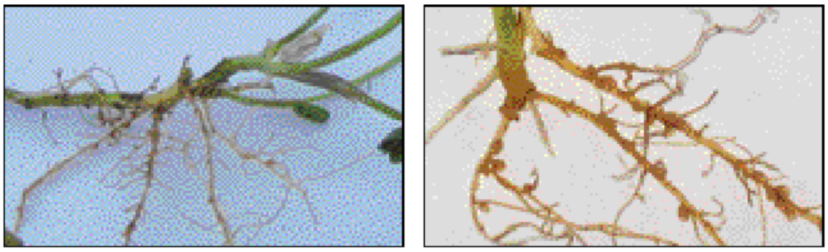

Plate 1. Nodules on white clover roots containing *R h iz o b ia* bacteria capable of supplying 120 units N/acre (150 kg/ha) in the soil each year. These nodules are a home-grown fertilizer N factory.

Around 79% of the earth's atmosphere is in the form of inert N gas. This N is of no use to plants unless it is converted into a form that is available to plant roots in the soil. *R h iz o b ia* bacteria have the ability to convert atmospheric-N into ammonium-N. This process is known as biological N fixation. Ammonium-N is a form of N that plants are able to take up from the soil and use for growth in m o re-or-less the same way as they would use fertilizer N. Fo r example, CAN fertilizer is Calcium Ammonium Nitrate whereas urea fertilizer is basically a concentrated form of Ammonium.

The selection and breeding of agronomic strains of white clover and *R h iz o b ia* bacteria has lead to the development of symbiotic combinations with the capacity to make up to 120 units per acre (1 50 kg/ha) of N available for plant uptake in the soil each year. Taken at today's prices and at the replacement cost of CAN fertilizer (currently costing around €0.80/kg N) this supply of N can be valued at around €40 per acre (€100/ha).

To get the best economic returns from white clover it is necessary to use minimum fertilizer N inputs. When clover receives high inputs of fertilizer N it sees no need to waste resources by feeding carbohydrate to the *Rhizobia* and supply is stopped. The *Rhizobia* are starved of resources, fail to multiply, numbers go into decline and the nodules shrivel up. Hence, clover-based swards hardly respond at all to fertilizer N inputs of greater 80 units per acre (100 kg/ha). At Solohead we have seen little difference in the productivity of well-managed clover-based pastures receiving (i) 50 units per acre, compared with (ii) 170 units per acre (60 versus 210 kg/ha).

What happens if we put very high rates of fertilizer N on clover swards? The answer is that under most circumstances the clover will disappear out of the sward within a year or two (Figure 1). Adaptations for N-fixation limit the ability of clover to compete in the presence of very high levels of N fertilization. Modern cultivars of perennial ryegrass have been selectively bred to respond to very high rates of fertilizer N. These ryegrasses grow very rapidly and aggressively compete for light when available soil N is in plentiful supply. This means that in a mixed sward receiving high rates of fertilizer N the clover gets rapidly shaded out by the perennial ryegrass. No plant can survive for long without access to sunlight.

Under some exceptional circumstances white clover can survive alongside perennial ryegrass under high rates of fertilizer N. This generally occurs where there is some degree of depletion of the soil N reserves. Where a field has been under long-term tillage, for example, soil N reserves are depleted and clover can often dominate the sward for a number of years after reseeding, even under high fertilizer N inputs. Another situation is where reseeded swards are repeatedly harvested for silage. Repeated harvests deplete soil N reserves creating a low N environment in the soil even though the sward might be receiving relatively high inputs of fertilizer N. Clover can survive quite well under such circumstances although it is making no economic contribution to sward productivity.

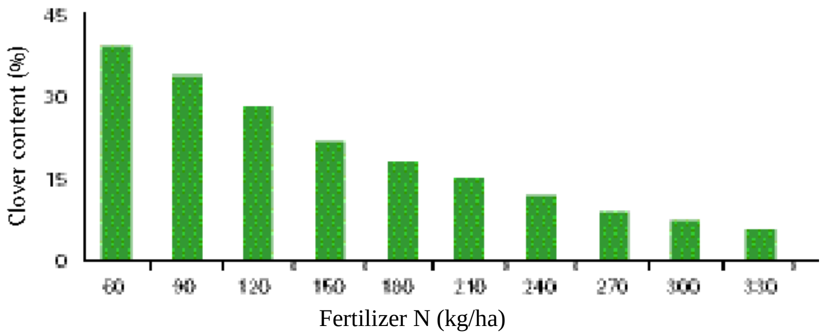

Figure 1. Increasing annual fertilizer N input will lower the clover content of grass-clover swards.

In well managed clover-based swards receiving low inputs of fertilizer N, the clover supplies N for pasture production in two ways: (i) directly by shedding nodules, roots and ungrazed material during the main grazing season; and (ii) indirectly via senescence of stolon over the winter and spring. Stolons (Plate 2) are runners that grow along the surface of the soil (a bit like the way ivy grows up a wall). Large quantities of stolons can accumulate on the soil surface during the summer months. 1-loweve r, during the period between the late autumn and the following April, up to three-quarters of the clover stolons end up being buried mainly due to the activity of earthworms (casting etc.) over the winter months. Much of the buried stolons die back over the winter. As this stolon rots in the soil, it acts like a slow-release fertilizer continually releasing N for uptake by the sward during the following year. 1-lighest rates of this slow-release fertilizer occur when soil tempera t u res rise during the late spring and summer. 1-lence, N fixed and stored in clover stolon in one year may not be released for grass growth until the following year.

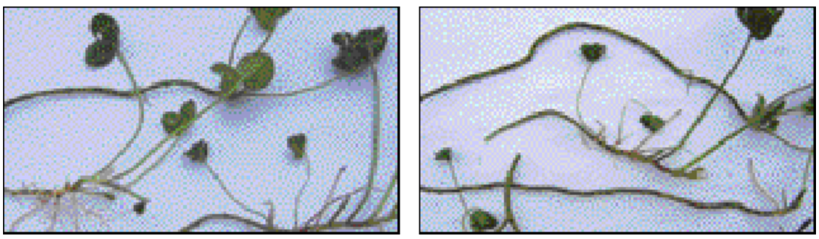

Plate 2. White clover stolon, roots (with nodules) and leaves

2.2. The growth habit of white clover

White clover is essentially a Mediterranean species. It likes warm, relatively dry but moist soil conditions and grows exceptionally well in the moist maritime-influenced Mediterranean climate experienced in New Zealand. Conditions in Ireland are just a little too cloudy, wet and cold for optimum clover performance.

One of the biggest differences between ryegrasses and white clover is the effect that soil temperature has on growth. Substantial amounts of grass growth commence when temperatures at 10 cm depth in the soil reach around 6°C. The growth of clover does not really take off until soil temperatures reach around 9°C. This means that, in spring, grass growth increases to appreciable rates of accumulation at some stage during March, whereas the accumulation of substantial amounts of clover does not commence until late-April (Figure 2).

On the basis of soil temperatures the clover growing year can be divided into two sections (Figure 2). Between late April and the end of October, soil temperatures are suitable for clover growth. From April onwards the clover starts to spread out via growth of stolons and make an increasingly important contribution to sward productivity. The clover content of the sward can increase to 40% during August. Large quantities of N are fixed under such circumstances because soil moisture and temperature conditions are conducive to high rates of N fixation. From early November to mid-April soil temperatures are too low both for clover growth and for N fixation. The clover goes into decline and eventual dormancy over the winter period.

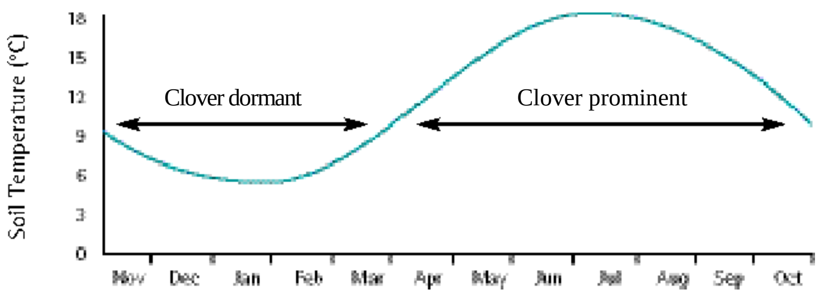

Figure 2. Soil temperatures (°C) during the year and impact on the clover growth

The seasonality of production of grass and clover in the swards at Solohead is presented in Figure 3. Clover makes little or no direct contribution to pasture production in spring. It starts to make an increasing contribution during May and from June onwards it has a substantial direct impact on sward pro d u c t iv it y. For example, in Figure 3, it can be seen that clover makes up around 35% of total production during August.

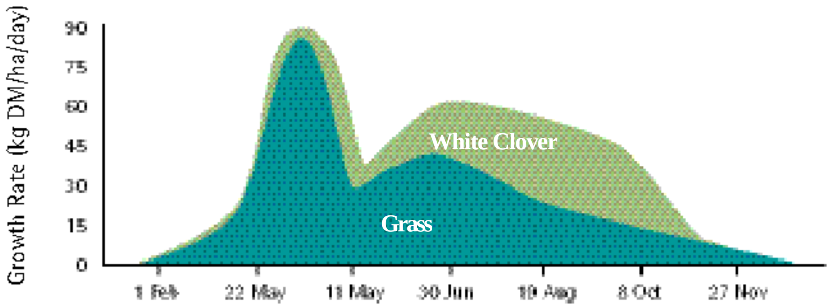

Figure 3. Changes in the grass and white clover content of swards during the year

It has sometimes been suggested that, because clover grows more slowly in spring, the growth of grass-clover swards will be slower than grass-only swards in spring. In reality, there is little difference at similar rates of fertilizer N input. The clover is virtually dormant during the early spring and makes little or no contribution to production. Spring production comes almost entirely from the grass component of the sward. During February and March, a gra s s - clover sward will respond to fertilizer N in much the same way as a g rass-only sward. At Solohead we have had the same turn-out dates to grass in spring and the same number of grazing days during the spring for grass-clover swards compared with grass-only swards receiving higher inputs of fertilizer N.

Clover leaves are very prone to frost damage. Over the winter, clover produces very small leaves that hide down in the sward canopy as an adaption to avoid frost damage. If there is no light getting down to the clover leaves and stolon during the winter and spring,

the clover has to use its stored reserves to survive the winter. The greater the period and extent of shading the more reserves are used up. The consumption of these reserves leads to the loss of stolon over the winter both in terms of the actual girth of individual stolon and total stolon length. Once reserves are consumed beyond a certain point the stolon starts to die back. On the other hand, if light is getting down to the stolon, the stolon is able to p h o t o s y n t h e s ise new re s o u rces on an on-going basis and has no need or, at least, less need to draw on stored reserves. Hence, the loss of stolon will be far lower under these circumstances.

The productivity of clover during the summer and autumn, when the clover is at its best, depends to a large extent on the amount of stolon that survives the winter and is present at the base of the sward during the late spring. As soon as soil temperature becomes favourable for clover growth, the clover stolon starts to expand in the sward. New stolon branch out and snakes its way throughout the sward sending up new leaves for consumption by gra z i n g livestock and new roots down into the soil, creating new locations for N fixation by the *Rhizobia*.

Keeping swards well grazed down during the winter and sp r i n g makes a big difference to clover survival and productivity during the following growing season. This practice ties in well with making most profitable use of pasture where it is possible to graze the whole farm during the spring. During the summer the clover really begins to thrive particularly where there has been no fertilizer N applied since the spring. High levels of pasture production, comparable with swards receiving high leve ls of fertilizer N input, can be achieved by well established clover swards from June onward s.

During the summer months clover stolon can increase by as much as two metres in length replenishing stocks of stolon lost over the w i n t e r. Biological N fixation also reaches peak leve ls during the period of highest soil tempera t u res during July and August. In d i rect contrast to the situation during the spring, long interva ls between grazing suits the clover very well.

Plate 3. During the late summer and autumn it can appear that clover dominates the sward. In this picture the clover represents around 35 to 40% of the sward dry matter.

White clover produces flowers rather intermittently at any time during the summer from May through to September. In general, flower production can be most prevalent during late June. However, this is influenced by weather conditions; sunny weather promotes flowering while cloudy weather tends to suppress it. In contrast to grass, there is little disadvantage associated with flower-head production by the clover either from the perspectives of sward acceptability to grazing livestock or sward nutritive value. Flower-head production can be suppressed by grazing fairly tightly during June and July and this is in accordance with good grassland management.

It can often appear that a sward is completely dominated by clover (Plate 3). In most instances appearances can be deceptive. In direct contrast to clover leaf morphology during the winter, during the summer the clover produces large leaves that lie at the surface of the sward. This can give the appearance of very high levels of clover in the sward. However, grabbing a fistful of pasture and examining it from the side rapidly dispels this illusion. While the wide clover leaves predominate the upper layers of the sward, the main bulk of the sward horizon is composed of grass leaves. (The clover leaves are a bit like umbrellas covering a crowd of people on a wet day. If seen from above, it seems like there is nothing but umbrellas, however, viewing from the side tells a different story; the umbrella corresponds to the clover while the people represent the grass component of the sward).

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2.3. Soil type and white clover

White clover is a relatively shallow rooted species and therefore does well on fertile soils that maintain a relatively high soil moisture status during the summer months. However, it does not tolerate being water-logged very well and clover does not do well on wet soils. The *Rhizobia* bacteria associated with clover perform best in soils with a high lime status and therefore clover does not grow very well in acid and, in particular, peat soils.

Although clover is quite shallow rooted it is able to survive drought on light soils reasonably well. This is because the clover stolon (plate 2) acts as a reserve of resources during times of stress and helps the clover to tolerate the relatively short-duration drought conditions that we experience in Ireland. Clover will often recover faster from drought than other grassland species.

The *Rhizobia* bacteria associated with clover perform best in free-draining soils because the pore spaces in the soil remain relatively water-free. This allows atmospheric N to diffuse into the airspaces in the soil and down to the *Rhizobia* bacteria in the clover root nodules where they can convert it to plant-available N. Obviously, if the soil is water-logged the diffusion of atmospheric N to the *Rhizobia* in the clover roots is inhibited. *Rhizobia* also like warm soil conditions and waterlogged soils tend to be colder than drier soils. On the other hand, the process of biological N fixation requires the presence of at least some available water in the soil.

Therefore most N fixation takes place during the summer months when soil temperatures are high and soils are relatively dry but not suffering from drought. A good example of this was 2003 when relatively wet conditions during May and June were followed by alternating wet and dry conditions during July, August and September. Very large quantities of N were fixed during this period of high soil temperatures because the pore spaces in the soil were never excessively waterlogged while the soil remained relatively moist.

The year 2002 was a very wet and difficult year for grassland management. Nevertheless, although soil at Solohead is fairly heavy and the farm is considered to be a relatively wet farm, the clover

performed remarkably well. In fact, the clover swards tolerated the wet conditions and performed better than the fertilized grass swards that were being used for comparison with the clover-based swards. The reason for this seems to be that the applied fertilizer was rapidly lost by denitrification due to the wet soil conditions whereas the biologically fixed N supplied by the *Rhizobia* was less prone to denitrification.

At the same time we were examining the potential of white clover under the very wet conditions at Kilmaley in Co. Clare. The clover failed to perform under the extremely wet soil conditions experienced at Kilmaley during 2002. This was largely due to the relatively persistent waterlogged conditions experienced on the shallow heavy gley soil on the farm.

Clover can be expected to perform best and to make the greatest contribution to pasture productivity on free-draining loam soils. These soils are light and therefore warm up relatively quickly. They are also free-draining and both of these conditions promote N fixation by the *Rhizobia* bacteria. Furthermore, grassland on these soils can be grazed over a long grazing season because they are less prone to poaching damage. This combination of circumstances suits the performance and survival of clover very well. Although these soils tend to have a lower background N supply than some heavier and deeper loam and clay-loam soils, much of this difference can be counter-balanced by the extra quantities of N fixed by the *Rhizobia-clover* association on these soils. The major limitation for N fixation and pasture productivity by grass + white clover swards on these soils is the incidence of drought conditions, which is a problem whether or not the clover is present.

It is fairly obvious from some of the results presented in this handbook that clover also makes a very valuable contribution to grassland productivity on heavier and wetter moderately drained soil at Solohead. The clover swards at Solohead have preformed remarkably well over the last six years and it is clear that clover is well able to tolerate the conditions on the farm and make a valuable contribution to grassland productivity.

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2.4. The long-term survival of clover in grassland

It has often been said that, in some ways, clover is the victim of its own success. Once clover becomes established in a sward , particularly under low N inputs, it will tend to dominate the sward for the first few ye a rs. This is because it has a clear competitive a d vantage over the grass in the sward because the clover has an independent supply of N. However, each year the clover sheds more roots, nodules, stolons, un-grazed above-ground herbage and this all contributes to the N supplying capacity of the soil. This favours the production of the grass component of the sward. However, it also creates greater competition for sunlight and soil nutrients such as P and K. This will tend to lower the clover content of the sward.

Another aspect of clover is that it is not perennial or permanent in grassland in the same sense as perennial ryegrass. Once introduced into a sward it generally has a life-span of three to eight ye a rs depending on factors such as the cultivar sown, soil conditions and g ra s sland management. In other word s, most of the clover will eventually die out of the sward due to old age. This loss of clover is often called the 'clover cra sh', which is an unfortunate term in d ic a t ive of disa s t ro us circ u ms t a n c e s. Our experience is that this loss of clover is less like a crash and more like a slow decline, unless the loss of clover is accelerated due to bad management, particularly herbicide use, or adverse weather conditions such as a wet autumn leading to high covers over the winter.

Under normal circumstances the clover content declines slowly and virtually disappears from the sward over time. However, there is a large residual impact of clover on soil fertility. Even as the clover content of the sward declines to low levels, sward productivity can subsequently remain very high for a year or two. This is due to the residual (slow-release) impact of the clover on soil N supply.

E ve n t u a l l y, soil N supply diminishes and the pasture begins to suffer from N deficiency. Under such circumstances, any surviving clover or naturally regenerating seedlings in the sward will develop and the clover can again dominate the sward after a period of a year or two. In the mean time, howeve r, sward productivity can d rop off before re c overing in re sp o nse to the increasing clove r

content of the sward. This cyclicity of production has been one reason why clover gained a bad reputation in the past, particularly where the combination of natural decline and unusually adverse weather conditions caused a relatively sudden drop in the clover content of the sward.

Armed with this knowledge we have designed a long-term management strategy that overcomes the problem of an ageing clover population. This strategy involves over-sowing 20% of existing clover swards each year on a five year rotation. Over-sowing involves mixing the clover seed with P El K fertilizer and broadcasting it onto grassland as a means of introducing new clover plants into the sward. Details of this technique are outlined in section 3.5. Using this technique on an on-going basis ensures that new clover is being introduced onto the farm all the time – in much the same way as replacement heifers are introduced into a herd of cows each year on an on-going basis. This approach ensures that young productive plants are constantly being introduced into swards and avoids the problems of older clover dying out of the sward. In this way the productivity of clover-based swards is maintained from one year to the next.

Figure 4 shows the productivity of swards at Solohead between 2000 and 2005. White clover was progressively introduced into these swards between 1 999 and 2002. These swards were fully converted to grass-clover at the end of 2002. In the four-year period including 2002 and 2005 between 10.8 and 11.8 t DM per ha was produced from grass-clover swards receiving less than 70 units per acre (90 kg/ha) of fertilizer N. There is some variation from year to year due to weather conditions; 2002 was a very wet year and cold conditions were experienced during May 2005 followed by drought conditions during July of the same year. In contrast, 2003 and 2004 were good grass-growing years.

Nevertheless, taking into account variations in weather conditions from one year to the next, the productivity of the established grass-clover swards between 2002 and 2005 were maintained from one year to the next. This can be attributed to maintenance of a productive clover component of the swards by over-sowing.

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The percentage clover in the sward each year is also shown in Figure 4. During 2001 the clover content of the sward was 24% compared to 21% in 2004. During 2001 the swards were in the early phase of conversion whereas in 2004 the clover swards were fully converted to clover. Although the swards in 2001 appeared to have a high clover content these swards were less productive than the same swards in 2004, which looked like containing less clover. This is a feature of swards that have been under clover in the long-term; the clover content of the swards settles down at around 20% (generally varying during the year between approximately 10% in April to 30% in August).

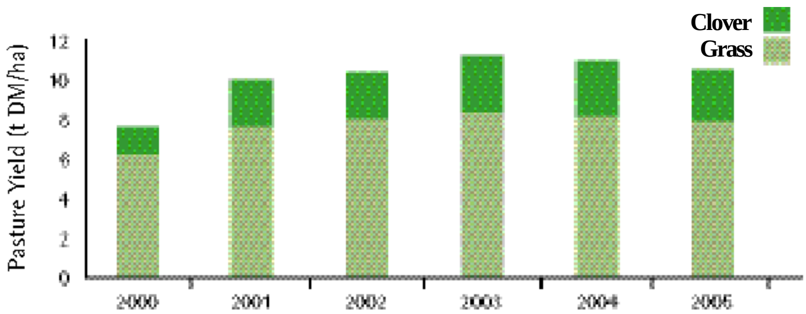

Figure 4. The productivity of grass + white clover swards at Solohead between 2000 and 2005. Clover was progressively over-sown into swards between 1999 and 2002 and 20% of the farm was over-sown each year subsequently.

Examination of Figure 4 reveals that the quantity of clover produced, in terms of kg DM per ha, in both 2001 and 2004 was identical. The big difference was that the accumulation of clover stolons and other material in the soil led to a build-up of soil fertility. This increase had a knock-on impact of increased grass production. The big difference between 2001 and 2004 was in the quantity of grass produced in both years. While total pasture (grass-clover) production increased by 22%, the quantity of clover remained the same and the quantity of grass grown increased by 29%. In other words, all of the increase in pasture production due to elevated soil fertility came from the grass component of the sward.

2.5. Productivity, nutritive value and carrying capacity

Under fertilizer N inputs of 50 units/acre (60 kg/ha), the presence of white clover in gra s sland increased DM production by a p p roximately 55% compared to the grass-only swards (Table 2). This can be directly attributable to biological N fixation associated with the clover. Furthermore, the presence of clover increased the crude protein content of the sward from 17% to 21% and the o rganic matter digestibility (OMD) from 80% to 82%. This improvement in nutritive value can be partly attributed to increased soil N supply as a consequence of N-fixation. It is also partly due to the clover having inherently higher nutritive value.

Table 2: Fertilizer N input to grass-only and grass-clover swards and pasture dry matter (DM) production and nutritive value

FERTILIZER N	GRASS-ONLY SWARDS				GRASS-CLOVER	
units/acre	50	140	185	285	50	170
kg/ha	60	170	230	350	60	210
DM yield t/ha	6.9	9.8	11.3	12.6	10.7	10.8
Crude protein %	17	20	22	23	21	21
OM digestibility %	80	81	82	82	82	82

When gra s s - c l over swards receiving low fertilizer N inputs (50 units/acre; 60 kg/ha) are compared to grass-only swards receiving moderate fertilizer N inputs (170 units/acre; 210 kg/ha), generally there is little difference in DM production or nutritive value or in the performance of grazing livestock. When gra s s - c l over sward s receiving low fertilizer N inputs are compared to grass-only swards receiving high inputs of fertilizer N (285 units/acre; 350 kg/ha), the g ra s s - c l over swards have around 85% of the carrying capacity of the high-input sward s. This is borne out by the dairy pro d u c t i o n experiments conducted at Solohead and beef and sheep production experiments conducted at Grange, Athenry and Knockbeg.

Table 3 shows clover-based swards compared to grass-only swards at two stocking ra t e s, 0.8 and 0.9 cows per acre (2.0 and 2.2 c o ws/ha). There were big differences between sward-types in the amount of N required to carry these stocking rates. There were also

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savings in the number of times fertilizer N was applied each year; the grass-only swards at the lower stocking rate received fertilizer on 4½ occasions each year and the higher stocking rate on 6½ occasions. This compares to fertilizer N applied on average on two occasions per year on the clover-based swards. For all systems the application of fertilizer N was costed at a standard rate of €3 per ha for each application.

However, the annual cost of over-sowing to maintain the clover content of swards averaged over the whole-farm area amounted to €6 per acre (€14/ha) giving a net annual saving of €29 per acre (€73/ha) at the lower stocking rate and €47 per acre (€116/ha) at the higher stocking rate. Therefore, for a farm similar in size to Solohead (140 acres; 57 ha) the net saving associated with having clover in grassland amounts to €4,160 at the lower stocking rate and €6,600 at the higher stocking rate. The lower stocking rate is compatible with REPS and is eligible for REPS payments amounting to €8,500. Therefore the lower stocking rate system has the potential to contribute €12,700 to farm income.

Research in other countries such as Denmark and France has shown that swards with high clover contents can be more difficult to ensile than grass-only swards. While this is true it is not very relevant to conditions in Ireland. At Solohead almost the entire silage requirement is made as first-cut harvested during May. The clover content of this silage is generally between 5 and 10% (Figure 3) and therefore has no impact on the ensilability of the harvested material. We have found similar yields of silage from clover-based swards receiving 70 units per acre (86 kg/ha) of fertilizer N compared with grass-only swards receiving 92 units per acre (114 kg/ha) (Table 4). The fertilized grass-only swards had slightly (3%) higher yields but slightly lower digestibilities (2%). The net effect is very similar yields of digestible herbage per acre.

Table 3. Stocking rates, fertilizer N input, costs of over-sowing and economic benefit of clover-based compared with grass-only swards

	Grass-only swards		Grass-clover swards	
Stocking rate (cows/ha)	**2.0**	**2.2**	**2.0**	**2.2**
Stocking rate (cows/acre)	0.8	0.9	0.8	0.9
Stocking rate (kg org. N/ha)	170	187	170	187
Milk output (gallons/cow)	1375	1375	1375	1375
Milk output (gallons/acre)	1100	1235	1100	1235
Fertiliser N (kg/ha)	**170**	**230**	**70**	**90**
Fertilizer N (€/ha)	125	175	46	59
Fert. application (times/ha/yr)	4.5	6.5	2.0	2.05
Cost of application (€3/ha/time)	14	20	6	6
Fertiliser N costs (€/ha)	**139**	**195**	**52**	**65**
Fertiliser N costs (€/acre)	56	79	21	26
Saving in fertiliser (€/ha)			87	130
Saving in fertiliser(€/acre)			35	53
Cost of Over-Sowing Clover				
	per ha	per acre		
Sowing rate	3.5 kg	1.4 kg		
Cost of seed at €10/kg (€)	35	14		
Spreading (two runs) (€)	6	3		
Cost of fertiliser (€220/t) (€)	28	11		
Cost of over-Sowing (€)	69	28		
Annual cost of over-Sowing (€) (once every five years)	14	6		
Net Benefit (€/ha)			**73**	**116**
Net Benefit (€/acre)			29	47
57 ha or 140 acre farm			**€4,160**	**€6,600**
REPS payments			€8,570	-
TOTAL			**€12,730**	**€6,600**

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Table 4. Yields of grass harvested for silage, digestibility, crude protein and pH of silage produced for grass-only swards receiving fertilizer N input of 92 units per acre (114 kg/ha) compared with grass-clover swards receiving 70 units per acre (86 kg/ha)

Year	Yield (t DM/ha)		Digestibility (°it)'		Crude protein (°it)		Silage pH	
	Grass-clover	Grass-only	Grass-clover	Grass-only	Grass-clover	Grass-only	Grass-clover	Grass-only
2000	6.6	6.8	78.2	76.2	15.8	15.8	4.1	4.1
2001	7.6	7.8	77.4	76.5	14.4	14.5	3.9	4.0
2002	7.6	7.8	77.3	75.7	15.7	15.8	3.8	3.9
2003	6.9	6.9	78.0	77.5	17.2	16.1	—	—
2004	5.9	6.3	80.0	78.1	22.2	21.3	—	—
Mean	6.9	7.1	78.1	76.8	17.1	16.7	3.9	4.0

'Organic Matter Digestibility of herbage harvested for first-cut silage

We have also found that the clover-based swards had higher crude p rotein contents, which may be attributable to the slightly lower yields and higher clover content. Clover maintains a higher crude p rotein concentration than perennial rye g ra s s. The clove r - b a s e d swards produced silage with similar preservation characteristics. This might have more to do with the lower input of fertilizer N than the c l over content of the sward. Exc e s s ive inputs of fertilizer N can result in poor quality silage. When it comes to applying fertilizer N for silage, it is usually better to err on the side of a little too little rather than a little too much. Ove rall, differences between the c l over-based swards and the grass-only swards receiving higher inputs of fertilizer N were very small.

On average, N uptake in first-cut silage was 1 53 units per acre (189 kg/ha) for the gra s s - c l over swards and 154 units per acre (190 kg/ha) for the grass-only swards. This clearly indicates the capacity of the clover stolons to supply N during the late spring and early s u m m e r, a time of year when the rates of direct fixation are relatively low. In terms of N taken up by the sward, approximately 36 units per acre (45 kg/ha) came from the natural backgro u n d fertility of the soil, 24 units per acre (30 kg/ha) from slurry and another 24 units per acre (30 kg/ha) was supplied by the clove r stolon. These results are supported by soil measurements conducted at Solohead between 2000 and 2005 where we have found similar levels of N availability in the soil under fertilized grass-only swards and grass-clover swards receiving lower inputs of fertilizer N.

3. INCREASING THE WHITE CLOVER CONTENT OF SWARDS

There are three ways of increasing the quantity of white clover in swards.

(1) Direct reseeding

(2) Over-sowing

(3) Promoting the existing clover

The least cost-effective way of introducing clover into swards is by direct reseeding, although it is necessary in some circumstances where the sward is badly run down and infested with troublesome weeds such as bent grasses and other undesirable grass species. The most cost effective way is by promoting existing clover in swards using appropriate grassland management techniques. Over-sowing was developed to maintain the long-term productivity of swards at Solohead. It is a necessary and integral component of the system. It can also be used as a low-cost method for introducing clover into permanent grassland without the need for cultivation.

3.1. Choice of white clover cultivar

White clover seed is often included in grass seed mixtures to no effect. The clover is usually killed off by one of a number of reasons such as the clover seed being buried too deep, sown too late in the year, herbicide use following establishment or high fertilizer N input to the established sward. There is no point in sowing white clover in the seed mixture unless you are prepared to mind the clover and make it work for you. This means cutting back on fertilizer N and allowing the clover to supply N via biological fixation.

The Irish recommended list is limited to five white clover cultivars (DAFRD, 2006). The Northern Ireland recommended list is far more comprehensive (DARD, 2006). Both lists are presented in Table 5. It can be seen that clover cultivars are divided into three categories based on leaf size. In general, small-leaf cultivars are lower yielding but more persistent than large-leaf cultivars and vice versa. Medium-leaf cultivars, in general, are intermediate in terms of both yield and persistency.

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Plate 4. Small-leaf cultivars are recommended for sheep

In the past, medium-leaf cultivars were recommended for general reseeding of permanent grassland and the large-leaf cultivars were recommended for short-term leys in rotation with arable crops. The reason that the large-leaf cultiva rs were not recommended for general use was their lack of persistency. However, experience has shown that white clover cultiva rs, re g a rdless of leaf size, do not p e rs ist indefinitely in swards even with good management. In general, the productivity of the clover will tend to decline after a period of around five years.

Small-leaf cultiva rs are generally recommended for sheep becaus e they are more tolerant of grazing by sheep. Because of the high digestibility of clover herbage, grazing sheep select the clover to the extent that the proportion of clover in the herbage consumed is higher than in the available pasture. This selective grazing can be detrimental to the clover particularly because sheep sometimes strip out the stolon from the base of the sward. Small-leaf cultivars are much better able to tolerate this because the stolon tends to be small and stringy and is tightly held to the ground.

Table 5. Recommended white clover cultivars for 2006

	DAFRD - Ireland	DARD - Northern Ireland

Cultivar	Classification (leaf size)	Rel. Yield	Rel. Yield	Persistence 0-9
AberAce	small	—	56	6.1
Kent wild white	small	—	49	6.2
Gls Demand	small	—	81	6.4
Crusader	small	—	108	5.8
AberHerald	medium	97	98	5.0
Avoca	medium	98	102	5.9
AberDai	medium	—	100	5.5
Chieftain	medium	102	127	5.5
Alice	large	102	111	5.2
Triffid	large	—	111	5.4
Barblanca	large	—	113	5.5
Aran	large	103	115	4.2

Cattle and dairy cows are far less selective grazers than sheep and they consume clover in proportion to its content in the sward. They also graze less close to the ground than sheep. Therefore small-leaf cultivars are more at risk of being shaded out of a sward grazed by cattle than large-leaf cultiva rs. Large-leaf cultiva rs grow more aggressively (hence higher yielding) and are better able to compete in swards grazed by cattle, albeit over a shorter lifetime. The problem of long-term persistency can be dealt with by over-sowing on a regular basis.

If reseeding with the intention of promoting white clover in swards for beef and dairy cattle, a 50:50 mixture of large-leaf and medium-leaf cultiva rs is recommended, although the sm a l l - l e a f cultivar Crusader would also seem to have a lot to offer in terms of yield and persistence. The recommended sowing rate of clover is 1.0 to 2.0 kg seed per acre (2.5 to 5.0 kg/ha). The lower rate is recommended following crops such as maize etc. The higher rate is recommended in gra s s - t o - g rass re s e e d s. The clover seed is sown with around 10 to 12 kg perennial ryegrass seed per acre (25 to 30 kg/ha).

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It is always a good idea to sow a mixture of cultivars in order to avoid keeping all of your eggs in one basket. If one cultivar lacks persistency in the sward there are others that will take its place. For sheep a suitable mixture of clover cultivars could contain Avoca, Crusader and Grasslands Demand. The emphasis of this blend of clover cultivars is more on persistence than yield. For beef and dairy swards, a suitable mixture could contain Crusader, Avoca, Chieftain and Aran. This blend is targeted more towards yield rather than persistency.

3.2. Grasses to sow with white clover

An important part of reseeding is deciding on which pere n n ia l ryegrasses to include in the seed mixture. Perennial ryegrasses show a progression of heading dates from around mid-May through to mid-June (Table 6). Grass seed mixtures containing a high p roportion of late-heading diploids are recommended for sowing with white clover. Clover fits in well on farms where it is possible to g raze over a long grazing season, where cows are turned out to grass as they calve in February and remain at grass until the end of N ovember or early December. The longer the grazing season the better suited clover is to the system.

Table 6. Department of Agriculture recommended perennial ryegrass cultivars for 2005

Cultivar	Heading Date	Rel. Yield	Persistence (1 to 9)	Spring growth	Autumn growth
DIPLOID PERENNIAL RYEGRASS CULTIVARS					
Donard	9 May	100	6.6	103	101
Spelga	16 May	99	6.7	100	102
Cashel	18 May	100	7.2	96	100
Shandon	20 May	100	7.2	105	102
Respect	22 May	98	7.0	101	97
Premium	25 May	98	7.0	101	101
Gilford	3 June	97	7.1	86	94
Denver	4 June	98	7.4	94	94
Soriento	5 June	98	7.5	96	95
Tyrone	5 June	97	7.3	90	98
Portstewart	6 June	98	7.0	97	98
Cancan	11 June	97	7.4	91	101
Cornwall	11 June	96	7.1	90	98
Twystar	14 June	97	7.3	95	97

Table 6. Department of Agriculture recommended perennial ryegrass cultivars for 2005 (Cont).

Cultivar	Heading Date	Rel. Yield	Persistence (1 to 9)	Spring growth	Autumn growth
TETRAPLOID PERENNIAL RYEGRASS CULTIVARS					
Anaconda	7 May	101	6.3	97	99
Magician	18 May	102	6.2	113	104
Napoleon	19 May	100	6.1	105	95
Fornax	25 May	100	6.7	86	97
Edda	27 May	102	5.8	96	101
Greengold	28 May	100	6.3	90	107
Delphin	31 May	105	6.4	116	102
Orion	31 May	101	6.6	106	96
AberCraigs	2 June	102	6.3	114	97
Glencar	3 June	103	6.4	105	92
Navan	3 June	104	6.4	101	108
Condesa	7 June	98	6.8	90	100
Mammout	7 June	99	6.8	84	103
Millennium	9 June	99	6.5	98	103
Sarsfield	10 June	101	6.8	84	104

Although it might seem para d oxical, later heading cultiva rs offer many advantages on farms where early turnout to grass is a priority. When it comes to grass supply during February and March, the heading date of a cultivar has little bearing on grass supply relative to gra s sland management factors such as building cove rs during the autumn, closing cove rs between October and December and fertilizer N use during the spring. Spring growth values presented in Table 6 should be treated with caution because they reflect growth up to mid-April rather than capacity to supply grass for gra z i n g during February and March. A number of experiments conducted at M o o repark and Grange have shown that there is little differe n c e between the capacities of cultivars with different heading dates to supply grass during February and March.

G rass growth during the spring is variable from one year to the next. In ye a rs with particularly slow growth in spring and gra s s supply is tight on the farm; one option is to graze the silage ground for a second time before closing up. The knock-on effect of this is that there will not be enough time to build up high yields of herbage for silage harvested in late May. Getting a high yield per acre is an important part of minimizing the cost of silage per tonne in the pit taking into account that contractors generally charge for

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h a r vesting the silage on a per acre basis. Late-heading cultiva rs have an advantage in this regard. With late-heading swards, silage h a r vest can be delayed into the middle of June producing high yields and maintaining high digestibility once these swards have been grazed during the spring. This type of management also suits white clover very well. Late-heading cultiva rs also tend to have lower incidence of stemminess during the late spring and early summer which is the period of peak milk yield of sp r i n g - c a l v i n g herds or spring-lambing flocks.

Perennial ryegrasses are also classified on the basis of whether they are diploids or tetraploids (Table 6). These categories are based on m a n i p u l a t i o ns during the breeding pro c e s s. In practical terms, t e t raploids tend to produce marginally higher annual yields c o m p a red to diploids, while diploids result in more pers is t e n t longer-lasting swards.

White clover can make up around 30% of the sward or more during A u g ust and September, dies back over the winter, and makes up around 10% of the sward during the following April. This can leave the sward more open during the winter until the swards thicken up. Late-heading diploid cultiva rs produce the most dense and persistent swards. Therefore, for mixtures with clover, late-heading diploids produce good thick and dense swards which compensa t e for the tendency of clover to make swards more open.

In the past it has been suggested that tetraploid cultivars are more suited to white clover than diploids because tetraploids are more open and hence are less competitive with the clover. 1-lowever, using t e t raploids solely to facilitate the clover can result in very open swards which make them more prone to damage and lowers sward persistency. On most farms sward persistency is a more important consideration than annual yield, particularly at stocking rates that can be carried by gra s s - c l over sward s. Reseeding can cost in the region of €1 50 to €250 per acre and, therefore, reseeding regularly can be costly.

1-l o w e ve r, tetraploids tend to be slightly higher yielding and als o have slightly better ensilability characteristics. There are advantages in including tetraploids in a mixture. 1-loweve r, they should not

dominate the mixture. It makes sense to select a mixture with similar heading dates assuming that the sward will sometimes be used for silage production. For farms with a long grazing season where all of the silage is made as one large harvest of first-cut during late May or early June, a mixture with heading dates around the second week of June is recommended. Ideally, the grass-clover mixture should contain between three and six different ryegrass cultivars and the majority of these cultivars should be diploids. Tetraploids can be included as a minor component.

3.3. Methods of direct reseeding of grass-clover swards

There are a number of different ways of directly reseeding swards. This can involve the conventional approach where the old sward is burned off using a glyphosate-type product (Roundup, Gallup, Touchdown etc.) the old sward is grazed or cut off, the old sod may be ploughed down, or cultivated using a heavy disc or power harrow, lime is applied in line with recommendations, the ground is tilled ideally to create a relatively fine firm seedbed and sowing takes place using a seed drill or by broadcasting using a fertilizer spreader or seed barrow. There are many different variations of this approach.

However, it is important to remember that clover seed is very small. Ideally, it should be broadcast onto the soil surface and perhaps rolled in. There is no advantage in burying the seed. The risk of burying the clover seed too deep outweighs the risk of the clover seed drying out because it is too near the soil surface. Grass seed is mostly sold in mixtures that contain a small amount of clover; usually around 0.5 kg per acre (1.25 kg/ha) and less than recommended for grass-to-grass reseeds outlined above. One approach is to sow the grass seed mixture using a conventional drill and to subsequently broadcast additional clover seed onto the soil surface before rolling in.

The ideal time for sowing grass-clover swards is during April and May or during June and July. Generally from mid-April onwards conditions are ideal for reseeding; however, this involves taking land out of production during a period when there is considerable pressure to supply pasture to grazing livestock and for first-cut

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silage production. The latest safe sowing date for clover is mid-August. Sowing later in the year increases the risk of failure because poorly established clover seedlings are at greater risk of being killed off by cold conditions during the winter and by competition from the grass during the following spring.

The ideal time for reseeding on farms where all of the silage is made as first-cut is during late June and July although this is often a dry time of the year. There is generally a surplus of pasture on the farm in July and therefore, the opportunity exists for taking ground out of production for reseeding. Furthermore, the new sward becomes established during late July and August and is back in the grazing rotation by early September – a crucial time to have high covers of pasture on the farm.

One method of spring reseeding is to under-sow a crop of spring barley or arable silage. Early harvest is important and there fo re under-sowing arable silage is preferred to spring barley. With arable silage it is important to choose a seed mixture that does not contain peas or vetches, which increase the risk of the under-sown grass and clover being smothered and killed out of the sward. It is also important that post-emergence herbicides are compatible with c l ove r. There are a number of herbicides that can give effective c o n t rol of bro a d - l e a ved weeds in establishing clover swards once they are applied at the right stage of development (see below).

Another method commonly used on farms is to burn off a sward to be harvested for silage with glyphosate and harvest the silage after a period of around 5 to 7 days. The gra s s - c l over seed mixture is then drilled into the surface of the dead silage stubble. This approach involves a certain amount of risk. It is important that a good kill of the old sward is achieved particularly where weeds such as bent grasses are a problem. A complete kill might not happen when there is a very heavy cover of grass on the field; some grass plants may remain protected lower down in the sward, particularly if the silage crop has lodged. Also the seed is being sown into re l a t i vely unfavo u rable seedbed conditions – not helped by the p resence of decaying tra sh and stubble. Neve r t h e l e s s, re s e e d i n g costs can be lowered to a certain extent using this approach.

Plate 5. It is important not to bury the clover seed during reseeding

3.4. Weed control in directly reseeded swards

One of the biggest reasons for incurring the expense of reseeding is the deterioration of sward botanical composition due to loss of perennial ryegrass and ingress of troublesome weeds such as bent grasses (Plate 6) and docks. In badly rundown swards the best option is to kill off with glyphosate and reseed. In swards badly infested with docks, there is a substantial risk of dock seedlings coming though in the re-sown sward. The best time to kill dock seedlings is before they reach around 100 days of age. However, this is more difficult to achieve than simply spraying within 100 days of reseeding. Many cultivated crop species have been selectively bred in such a way that most of the seed will germinate fairly rapidly after reseeding. Dock seeds do not behave in this way. Dock seeds have an innate mechanism that causes germination to be sporadic. In a reseeded sward many seeds will germinate alongside the sown sward but more will continue to germinate and come through during the following months. Remarkably, dock seeds can even germinate intermittently during the coldest months of winter in Ireland.

Under normal circumstances, where docks are not a major problem, the best post-emergence sprays to use for reseeded swards are products such as Legumex DB, Nintex and Undersown. Where chickweed is a problem Acumen and Alistell are recommended (Table 7). These sprays are safe to use on clover but

are relatively expensive and therefore spraying swards more than once with these products can be very costly. Therefore, it is important to spray before the weeds reach 10 cm (4 inches) in height and after the clover seedlings have reached the first trifoliate leaf stage. Seeding onto the soil surface and rapid establishment facilitates post-emergence weed control.

Table 7. Post-emergence herbicides for reseeded grass-clover swards

Product name	Chemical	Rate (litres/ha)
Acumen	Bentazone + MCPA + MCPB	5.0
Alistell	24DB + MCPA + Linuron	3.5
Legumex DB	24DB + MCPA	7.0
Nintex	24DB + CMPP	7.0
Undersown	24DB + MCPA	7.0

In some instances the old sward may be badly infested with docks. Under such circumstances it is likely that there has been a huge build up of dock seeds in the soil. A mature dock plant can produce 60,000 seeds per year and dock seeds can remain viable in the soil for many years. It is hardly surprising that there can be millions of viable dock seeds in the top 10 cm of badly infested swards. After reseeding the seeds in the top few centimetres will germinate to produce seedlings. This can amount to tens or even hundreds of thousands of seedlings per hectare. Taking into account that these seedlings can germinate and invade the sward over a prolonged period it is highly unlikely that a single application of herbicide will be sufficient to keep these seedlings under control.

Up until the dock seedlings develop a taproot, they can be killed quite easily using herbicides. Once they develop a taproot they become almost indestructible. In heavy infestations taking place over a protracted period of time it is likely that repeated applications of herbicide will be necessary to hit seedlings as they become established. This tends to preclude the use of the clover-safe herbicides included in Table 7 in favour of cheaper products such as CMPP (mecoprop-P; Duplosan), although this herbicide is deadly to clover.

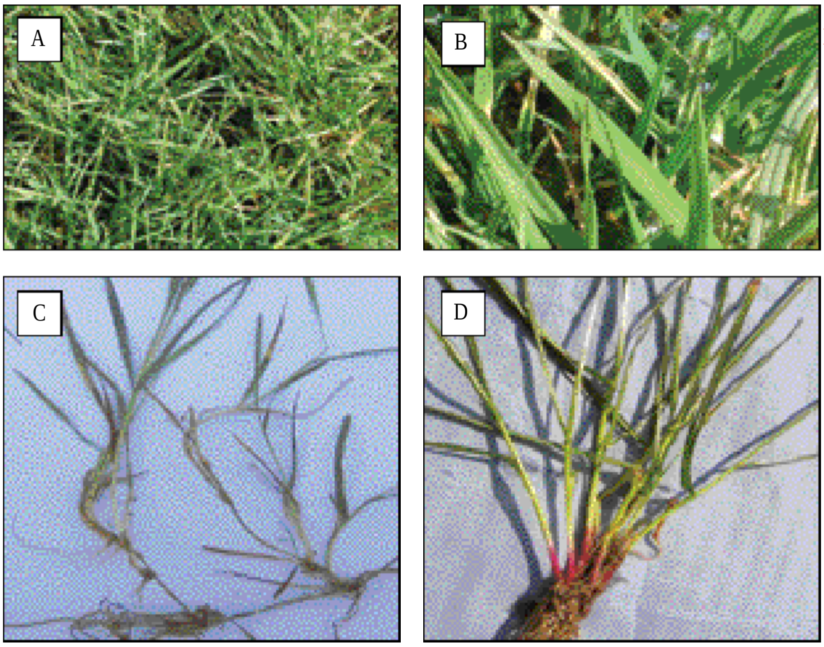

Plate 6. (A) sward with heavy infestation of bent grass; (B) close up showing flat sword-shaped leaves of bent grass; (C) growth habit of bent grass, note the flat leaves, rounded stem and stolons linking plantlets; and (D) growth habit of perennial ryegrass, note the pink-purple base of stem, flattened stem and leaves folded in on a distinct central crease, and tufted regeneration; new plantlets bud out from the base of older tillers (no stolons).

The recommended strategy is to cultivate and reseed with grass seed only – no clover is included in the seed mixture. After establishment it is necessary to check for dock seedlings in the grass crop on a regular basis – around every month or so. Dock seedlings are very small and fragile and tend to remain quite hidden in the sward until they develop a taproot. It is important to check carefully. One small dock seedling in a square meter of grass can easily go unnoticed. However, one dock plant per square meter equals 10,000 plants per hectare (4,000 per acre). To put this in context; a dense crop of sugar beet contains around 80,000 plants per hectare. Overlooking a few small dock seedlings can develop into a very serious dock problem within a couple of years. If there is at least one dock seedling per meter squared, it is necessary to spray and repeated applications may be necessary.

Once the dock seedlings have been eliminated from the reseeded sward using CMPP, clover seed can then be over-sown into the sward using techniques outlined in the following section. In general, it is relatively easy to establish white clover by over-sowing in young reseeds because they are usually quite open and the grass seedlings are not as competitive as an established grass sward.

3.5. Over-sowing white clover into permanent grassland

If the clover produces seed – why is there a need to over-sow the farm every five years? There are two aspects to the answer to this question. One issue is that it can take many years of grassland under clover for enough clover seed to build up in the soil seed reserve to sustain clover populations by natural regeneration – similar to the situation in New Zealand. The second is that clover plants are cross-pollinated by flying insects, primarily bees and bumblebees. Much of the cross-bred seed produced will be of lower production potential compared with the pure strains of commercially available cultivars. Introduction of selectively-bred cultivars is an important component of maintaining the long-term productivity of clover-based swards under Irish conditions.

The benefit of white clover in grassland in terms of savings in fertilizer N is around €35 per acre. It has been pointed out in the previous section that direct reseeding can cost around €150 to €250 per acre. This means that it can take many years for the clover to pay for itself if introduced into grassland by direct reseeding.

Over the last six years we have been examining ways of introducing clover into swards at low cost. A simple and low cost method of introducing white clover into grassland is to over-sow the white clover seed by mixing it with fertilizer such as 0:7:30 and to spread it over the sward after first-cut silage. The total cost of this approach is around €28 per acre or, if spread over five years, around €6 per acre per year. This leaves a net benefit of €29 per acre per year. This approach works well for open swards when soil moisture is adequate and the sward is kept well grazed out for the remainder of the year. It is not suited to old butty swards or swards that are badly infested with weeds such as docks, thistles, dandelions etc. In cases such as these it is probably better to burn

off the sward with a glyphosate-type product (Roundup etc.) and carryout a full reseed.

Over-sowing costs are minimised in order to maximise the benefit of having clover on the farm. Techniques using strip or slot seeders are not recommended because they increase costs and lower profit without improving the rate of successful clover establishment. There is also a lack of availability of suitable machinery in most parts of the country. Strip or slot seeders or scratching the soil surface with a harrow can damage the sward and open up the sward to dock infestation.

Low doses of herbicides such as paraquat (e.g. Gramoxone) are sometimes used to knock back the grass in order to allow the clover to become established. We see this as counterproductive because paraquat will knock back ryegrass more than undesirable rhizomatous grasses such as bents and scutch. Bent and scutch grasses produce underground rhizomes that remain protected from the paraquat which is a herbicide that kills on direct contact. Grasses such as bent and scutch are able to rapidly regenerate from the underground rhizomes and can subsequently come to dominate the sward. This is not a good result. At Solohead, we use a high rate of clover seed (2 kg/acre) to overcome the problem of slugs as a lower-cost option than using slug pellets. Over-sowing is a simple and low-cost technique that is as effective as higher cost and more complicated methods.

Over-sowing has been used at Solohead for six years both to increase and maintain the white clover content of swards. It has mostly worked well; poor results have occurred when dry weather and soil conditions follow over-sowing. It is impossible to predict what the weather will do from one year to the next. Therefore there is a certain amount of risk associated with this approach. Over-sowing at Solohead and on farms is generally between 70 to 80% successful although this varies considerably from year to year, soil type and the amount of rainfall received in different parts of the country.

Poor results have also been due to allowing the grass get too strong after over-sowing. This is the single biggest reason for failure that lies within the farmer's control. The importance of tight grazing after over-sowing cannot be over-emphasised. The single most

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important recommendation, which can greatly improve the success of over-sowing is tight grazing for the remainder of the year.

Pre-establishment management

The first thing to get right is soil fertility and, in particular, lime. The *Rhizobia* bacteria that fix N in association with clover are more p ro d u c t i ve in soils with a p1-I of between 6.5 and 6.8. There fo re , getting a soil test carried out and applying lime is the first step to take before over-sowing. The P content of the soil is als o important. White clover seeds are very small and clover seedlings tend to be relatively fragile. Seedling vigour is favoured by having plenty of P in the vicinity of the establishing seedling. Therefore, it is usually recommended that clover seed is broadcast with a fertilizer that contains P – as this will favour establishment.

It is also usually recommended that the clover seed sown is pelleted. The coating on the pelleted clover seed contains some P and also some *Rhizobia* bacteria that form a symbiotic relationship with the c l over once it establish e s. Pelleting almost doubles the weight of the clover seed. The cost of a 25 kg bag of pelleted seed is usually the same as a 25 kg bag of unpelleted or naked clover seed. This means that you are buying less seed per bag when you buy pelleted seed. Some recent research indicates that the evenness of spread of broadcast naked clover seed is the same as that of pelleted seed. T h e re fo re, when naked seed is broadcast at the same rate much m o re clover seed is being applied. 1-Ioweve r, the same re s e a rc h showed no clear advantage of naked seed over pelleted seed and vice ve rsa in terms of success of establishment of clover in the s w a rd. There fo re, the main determinant of which type to us e depends on the cost of the seed.

Successful establishment of clover in the sward by ove r - s o w i n g depends on:

(i) Contact between the soil and the seed.
(ii) Moist soil conditions.
(iii) Light penetrating down to the clover seed and seedlings.
(iv) Strong well-established seedlings to survive the winter.

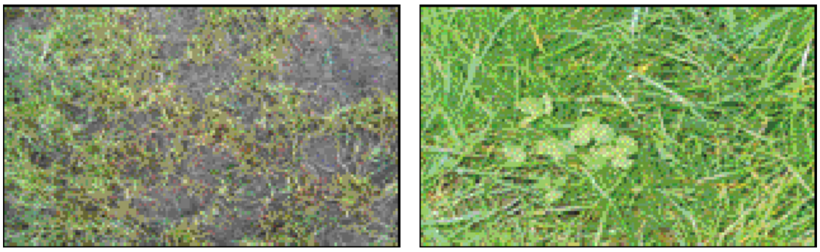

Plate 7. An open sward and moist soil conditions provide ideal conditions for introducing clover seedlings by low-cost over-sowing method. Clover seedlings become established in open patches in the sward. It is important that the sward is kept well grazed out after over-sowing.

It is important that the clover seed comes in contact with the soil surface. This means that over-sowing works best when there is an open sward. Experience on farms has also shown that, in general, over-sowing works best after a harvest of silage during May or early June, compared to grazed swards. Over-sowing can also work on grazed swards although not generally as successfully as after silage. This is because the grass recovers more quickly after grazing than after a heavy cut of silage. This creates more competition for the establishing seedlings. Hard grazing before and after over-sowing grazed swards is important to ensure success. One method that works well is where a leader-follower system is in operation. The sward is partly grazed by dairy cows. The clover seed is broadcast and walked in by followers allowed in to graze out the sward.

Soil moisture conditions have a major influence on the success of over-sowing. In general, highest rates of rainfall are recorded during the winter and lowest rainfall during May, June and July. This means that the soil is wet during the winter and remains fairly wet during the spring. However, the ground gets progressively drier during the summer months as water drains away or is removed from the soil by evapo-transpiration. Highest rates of evapo-transpiration are recorded during May, June and July. Indeed, more water is removed from the soil by evapo-transpiration during these months than is supplied by rainfall. In general, the driest soil conditions occur in August.

Rainfall can vary a lot from year to year. In Table 8 it can be seen that, in the period between 2001 and 2004, 2002 was an exceptionally wet year with around 45% higher rainfall compared to

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2001 or 2003. This obviously has a big influence on soil moisture conditions during the year. There are also big differences between d i f f e rent locations with lowest rainfall being re c o rded in the east and inland areas and higher in more westerly and coastal areas.

Table 8. Annual rainfall (mm) at sites around Ireland between 2001 and 2004

	2001	2002	2003	2004
Ardee	614	1147	665	715
Solohead	796	1149	845	1000
Moorepark	839	1201	882	1033
Ardfert	922	1165	914	1065
Wexford	1015	1401	982	960
Dungarvan	1188	1472	1027	1044
Ballinamore	1047	1703	1049	1210

Rainfall combined with evapo-transpiration and soil type influences soil mois t u re status which is usually expressed in terms of soil m o is t u re deficit (SMD) during the summer months. Higher SMD values reflect drier soil conditions. Under wet conditions during the late autumn, winter and spring, soils have SMDs in negative figures or close to zero. Good grass growing and grazing conditions are seen when SMDs are between 10 and 25. The ground gets i n c reasingly hard as SMDs approach 50 and grass growth is increasingly restricted by drought as SMDs increase above 50.

It can be seen in Figure 6 that there are large differences in SMDs during the summer months in different parts of the country. In the northwest the average accumulated SMD between May and August is around zero and does not exceed 25 over much of the north and west of the country. However ave rage SMDs between May and August are around 50 in the southeast. This can vary considerably with soil type. During the summer months SMDs can be quite severe on light free-draining soils but much less of a problem on heavy gley-type soils.

Soil moisture deficits and successful establishment

Soil moisture deficits have an important influence on the success of over-sowing. The farm at Solohead is located on a heavy clay-loam soil in southwest Tipperary. Annual rainfall levels are moderate (see

Table 8) but wet soil conditions can often make grazing difficult to manage during the spring and autumn and during wet summers like 2002. Es t a b l ishment in all paddocks over-sown with clove r during 2002 was very high with densities of between 50 and 100 s e e d l i n gs per metre squared. Ta rget seedling densities are aro u n d 50 per metre squared. Pro d u c t i ve clover swards can be achieve d with lower leve ls of establishment with a high standard of post-establishment management.

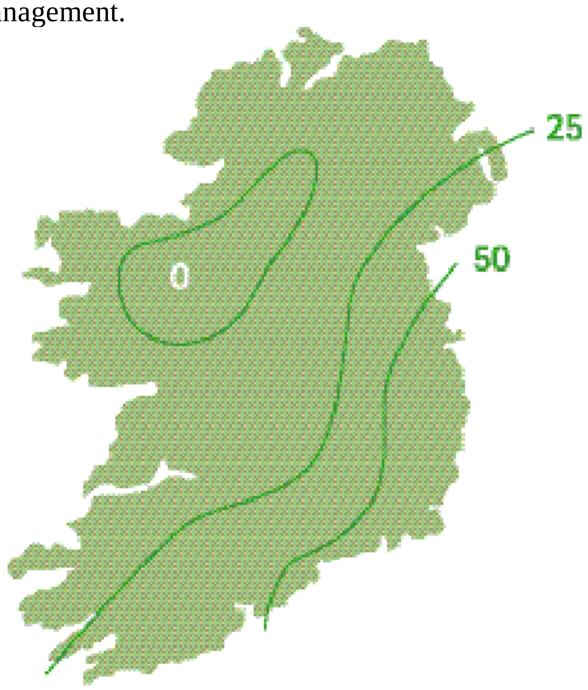

Figure 6. Soil moisture deficits (mm) between May and August (seven year average)

High leve ls of establishment were also re c o rded during 2003 although this was a much drier year than 2002. Po o re r e s t a b l ishment was re c o rded during 2004 with seedling dens i t i e s g e n e rally between 25 and 50 per metre squared, although 2004 was a wetter year than 2003 (see Table 8). This difference is due to differences in soil moisture conditions at around the time of over-sowing and afterwards between these two years (Figure 7).

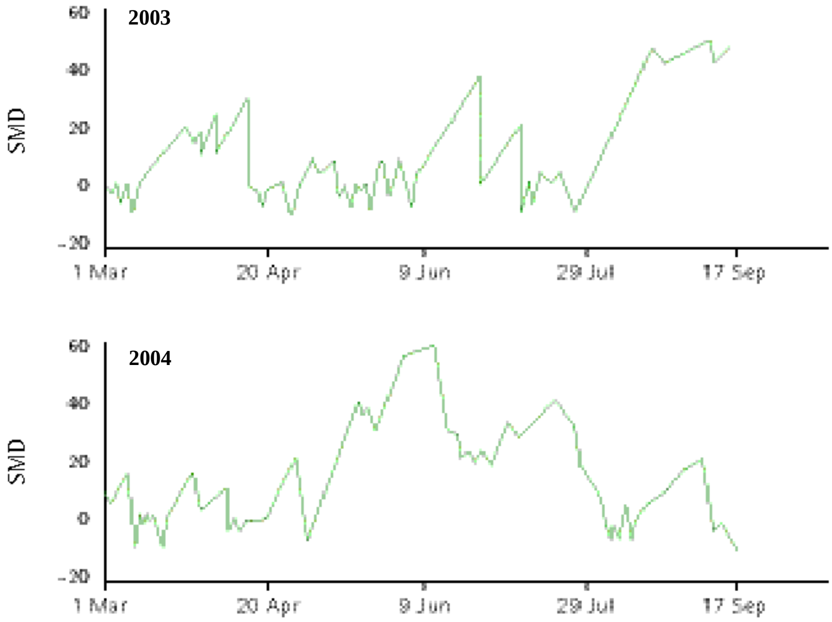

Figure 7. Soil moisture deficits at Solohead between March and September 2003 and 2004: 0 = wet, 10 to 25 = good grass and grazing conditions, >25 = ground getting dry and hard, >50 = grass growth increasingly restricted, > 75 = drought conditions.

It can be seen in Figure 7 that SMDs were low between late April and mid-June 2003. Over-sowing took place after silage in late May and there fo re the clover seed germinated on moist soil and t h e re was sufficient mois t u re to allow the seedlings to develop a network of roots which is vital for seedling survival. From mid-June to late July 2003, SMDs fluctuated between 0 and 40 and these c o n d it io ns were ideal for seedling survival. SMDs approaching 50 w e re re c o rded during September 2003 but, by this stage, the seedlings had a well developed root system and were well able to w it hstand the dry spell during late August and September, which was of relatively short duration.

Considerably different soil moisture conditions were experienced at Solohead during the summer 2004. SMD's increased steadily during May 2004 to reach 40 by the end of May and increased to 60 by

mid-June. Some paddocks were over-sown in mid-May and more were done at the end of the month. Better establishment was achieved on the earlier sown paddocks. The later sown paddocks had poorer establishment due to the deteriorating soil moisture conditions. Seedlings that established following over-sowing in late May were hit by drought conditions during June and a large proportion were killed off. Earlier sown seedlings had better developed root systems and were better able to withstand the drought conditions. One way or another 2004 was not a good year for clover establishment at Solohead compared to 2002, 2003 or 2005.

Improving the probability of successful establishment
There is an old saying that there will be one year in four when you wouldn't be able to make hay. Bad years for making hay are good years for over-sowing; 2002 was a clear example of this. Differences in the success of over-sowing can be expected from year to year and from place to place. Over-sowing will be more successful in wet summers, in higher rainfall areas in the west of the country, and on heavier soils. Over-sowing is a riskier proposition on drier sandier soils in eastern parts of the country.

Therefore, to improve the chances of success on drier soils in more eastern areas it is recommended that over-sowing is carried out early in the month of May. In general, it can be expected that SMDs will be low during late April and early May and will increase progressively, although erratically, during the summer months reaching highest deficits during August; the earlier over-sowing takes place the better. Ideal circumstances would be paddocks where surplus grass is removed as baled silage or where an early crop of first-cut silage has been harvested.

During the summer months SMDs for different parts of the country are printed in the back pages of the *Irish Farmers Journal* each week. If SMDs are low (between 0 and 20 for heavy soils and between 0 and 15 for light soils) and the forecast is predicting wet and broken weather there is a high probability that over-sowing will be successful. If SMDs are higher (up to 25) and the forecast is for continuing dry weather conditions then over-sowing becomes a riskier proposition, particularly on light soils. If SMDs are high (>25)

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then it is probably better not to attempt over-sowing because the likelihood of success is greatly diminished.

Keeping an eye on SMDs in the *Irish Farmers Journal* each week p rovides very useful information that can be used to reduce the element of risk associated with over-sowing. It is a good idea to check the figures for your local area before attempting over-sowing. These figures will give a rough indication of the likely soil moisture status in the area, which will vary on a more local level depending on soil type.

Some ye a rs are obviously going to be more favo u rable for ove r - sowing than others. There f o re, it makes sense to be flexible and opportunistic when planning how much of the farm to over-sow each year. This means having some clover seed on hand and doing more than planned during a wet May and less than planned in a dry May.

The SMD figures printed in the *Irish Farmers Journal* a re an indication of what is happening at that point in time. In general, SMDs are likely to increase, on average, during the summer months. However, a heavy spell of rain can often rapidly diminish fairly high deficits as, for example, can be seen to have happened on a number of occasions during 2003 (Figure 7). Soil mois t u re status can go from dry to wet in a matter of a day or two of wet weather. It is impossible to predict future weather conditions. When it comes to over-sowing, it is probably better to take the risk and over-sow at least some of the farm each year as a long-term strategy for maintaining clover in swards. A larger proportion of the farm, 25 to 30%, can be over-sown under favourable soil moisture conditions in wet years and a lower proportion of 10 to 15% in less favourable years with the long term strategy of over-sowing 20% of the farm, on average, each year.

Method of over-sowing clover into grassland

Research by Michael Healy and colleagues at Solohead has shown that good seedling distribution can be achieved by carefully mixing the clover seed with fertilizer and spreading the fertilizer plus seed with a fertilizer spreader at normal spreading widths. At Solohead the fertilizer plus seed is normally applied in two runs; the second run at right angles to the first, to ensure evenness of application.

To test the effectiveness of this approach, aluminium trays (up to 300 per field depending on field size) were laid out on the ground on a 15 m grid across various fields where fertilizer plus seed was about to be over-sown. After application, the number of seeds in each tra y was counted. These measurements were conducted over a larg e number of fields during three years. In general, there was no clover seed in less than one percent of trays. In other words, clover seed was effectively distributed to most parts of the field most of the time.

Plate 8. Pelleted clover seed is mixed with 0-7-30 fertilizer in preparation for over-sowing

The results of this research were far better than expected using both pelleted and naked clover seed. One big concern was the risk of the c l over separating out from the fertilizer during application. Fo r example, the clover seed might sink to the bottom of the spreader or vice versa due to shaking during application. This means that all the clover seed would be applied either earlier or later during the bout of application. Another concern was that the clover seed would not be propelled as far as the fertilizer by the fertilizer spreader. This second concern is not a problem for either pelleted or naked seed.

Nevertheless, great care is needed to avoid these potential problems. First of all the seed is mixed with the fertilizer in the field. Mixing the fertilizer and seed in the ya rd carries the risk of the seed s e p a rating out while driving down the lane to the field. As each bag of fertilizer is filled into the hopper, the clover seed is poured in simultaneously and mixed around at regular intervals by hand.

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Plate 9. It is recommended that watery slurry is applied to first-cut silage stubble after over-sowing.

Half of the fertilizer plus seed is applied in one run and the other half of the fertilizer plus seed is applied in the second run. When applying clover seed to a field for the first time an application rate of 2 kg per acre (5 kg/ha) of clover seed is recommended. When converting over to clover in the early years, it is beneficial to use aggressive large leaf cultivars that are better at gaining a foot-hold in a grass-only sward. If over-sowing to maintain the clover in an e x isting clover sward a mixture of cultiva rs should be us e d depending on whether the sward will be used for cows, cattle or sheep as outlined already. At Solohead this seed is applied with a bag of 0:7:30 per acre. Any type of fertilizer can be used but the fertilizer should not contain N.

When applying the fertilizer plus seed to a 10 acre field, for e xample, we apply 20 kg of seed along with 10 bags of fertilizer. The fertilizer sp reader is set to apply fertilizer at a rate of half a bag per acre. Half of the fertilizer (5 bags) and half of the seed (10 kg) are carefully mixed together as outlined above and applied up and down the field. Once the first run is completed, the remaining half of the fertilizer (5 bags) and the remaining clove r seed (10 kg) are again carefully mixed together and applied back and forth across the field. Ten acres is about the size of field that we would do at one time.

In fields that are fairly square, this alternate 'up and down' and 'back and forth' approach works well and ens u res evenness of spread. On long narrow fields applying the fertilizer plus seed 'back and forth' might not be practical. Under such circ u mstances the fertilizer plus seed should be also applied 'up and down' along the length of the field during the second run but running in between the tramlines of the first run.

Although alternative methods of over-sowing clover seed have not been tested in a systematic way, a number have been us e d successfully on farms. The most typical approach is the application of clover seed using a slug pellet applicator or grass seed applicator on the back of an ATV (quad-bike). Another is to use a Vicon fertilizer spreader with a 'grass seed' plate inserted to regulate the outflow of the clover seed. Measurements of seedling distributions on farms indicate that these approaches can be as equally effective as applying the seed with fertilizer. These 'fertilizer-free' approaches might be of particular relevance on organic farms. At Solohead we h a ve focused on the fertilizer plus seed approach because a fertilizer spreader is a piece of equipment that is available on most farms.

After over-sowing it is recommended that around 3000 gallons per acre (33 m^3/ha) of fairly watery cattle slurry (2 - 4% DM) is applied to the silage-stubble. This helps to wash in the seed and seal up the ground to lower moisture loss. This aids seedling establishment as well as supplying nutrients for plant growth.

Post-establishment sward management

The big advantages of over-sowing are (i) low cost and (ii) clover is introduced without destroying the existing sward and therefore the sward can continue to be grazed throughout the year. The problem for the clover seedlings is that they have to compete with the existing sward that is much more effective at competing for light, nutrients in the soil and, crucially during the summer months, soil water.

It can take a few months for the clover seedlings to get established and maintain their position in the sward. During this period it is n e c e s sary to minimise competition between the establish i n g seedlings and the existing sward. Minimising competition means (i)

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applying no fertilizer N for the remainder of the year and (ii) keeping the sward well grazed down. This means grazing the sward at least every four weeks or when covers are around 1000 kg DM per ha. It has been found at Solohead and Moorepark and fro m measurement on farms around the country, that *the single biggest reason for failure that remains within the farmer's control is not keeping swards well grazed out after over-sowing*.

In some instances there is the attitude that once the clover seed is over-sown, the gate can be shut and that you can forget about it. This is a recipe for failure and failure is a waste of money. There is no point in over-sowing clover seed unless a pro d u c t i ve clove r - based sward is developed. Broadcasting the seed is the simplest part of the pro c e s s. Po s t - e s t a b l ishment management is 80% of successful establishment of clover in the sward.

During the first establishment year, the clover will make little or no contribution to sward pro d u c t i v it y. It is only during subsequent ye a rs that the clover makes a substantial contribution to sward productivity and substantial savings in fertilizer N can be made.

Over-sowing to maintain productivity of existing clover swards At Solohead we have operated a policy of over-sowing 20% of the farm each year on a five-year rotation. It is much easier to establish clover in an existing clover sward by over-sowing. This is because (i) the swards tend to be more open; (ii) swards tend to be more digestible and can be grazed out to a lower base; and (iii) the existing clover continues to make a contribution to soil N supply and therefore there is no loss in productivity during over-sowing.

When over-sowing to maintain the clover content of existing clover swards, we use a lower rate of seed; between 1 and $1^1/_2$ kg per acre depending on the clover content of the existing sward. If there is more clover, we use less seed. When selecting cultivars under these c i rc u mstances we aim for a mixture with some emphasis on persistence as well as yield. During 2006, we are using a four-way mix of Crusader, Avoca, Chieftain and Aran, which is a mixture of one small, two medium and one large-leaf cultivar, combining the p e rs istence of the small leaf with the high yield potential of the large-leaf and the intermediate characteristics of the medium-leaf.

3.6. Promoting the existing clover in swards

Experience on farms has shown that promoting the existing clover in swards has been the most immediately successful method of getting clover into relatively large areas of farms. Direct reseeding can result in the rapid establishment of pro d u c t i ve clove r - b a s e d swards. 1-lowever, only a small proportion of a farm can be reseeded in one year. In general, larger areas of the farm can be over-sown without detriment to ove rall production. 1-loweve r, sward s developed by over-sowing take longer to become fully productive. W h e re there are existing swards containing clover these can be made productive relatively rapidly by appropriate management.

In some instances there are swards on farms that have been reseeded within the past four or five years. These swards were not reseeded with the intention of producing clover-based swards but in some instances they can contain a reasonable amount of clover. In other situations, particularly on re l a t i vely extens i ve farms, or parts of farms that are extens i vely managed, there can be a considerable amount of old clover in swards. The reason for this is generally because inputs of fertilizer N have tended to be low and t h is has promoted the survival of the old clove r. This old 'wild' clover is not as productive as newer cultivars but can be a valuable component of swards nonetheless. It is much easier to establish new clover cultivars in an existing sward that contains clover than in one that doesn't.

The three basic rules of promoting clover in existing swards are
(i) Cutting out fertilizer N from mid- to late April onwards,
(ii) Not spraying swards for docks even using 'clover safe' herbicides
(iii) Grazing out well during the autumn, winter and spring.

Cutting out fertilizer N to promote clover in swards
Where there are high inputs of fertilizer N, aggressive grass growth shades the clover out of the sward. Cutting back on fertilizer N

holds back grass growth allowing the clover to thrive. Some fertilizer N is important to drive on spring growth in grass-clover swards. Cutting out fertilizer N from late April onwards allows the c l over to increase in abundance. 1-loweve r, it often happens that once the fertilizer N is stopped the clover makes very little initial

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contribution to sward productivity. The reason for this is the clover has gone lazy. It has grown dependent on fertilizer N inputs. If clover is receiving sufficient N from other sources it will not fix any N of its own.

It can take a while for clover to develop the capacity to start fixing N. Stopping the input of fertilizer N triggers the clover to start releasing resources into the nodules to feed the *Rhizobia* bacteria. Firstly, it takes a while for this trigger mechanism to kick in because it takes a few weeks for N in the soil to be used up. Lack of N in the soil triggers the clover to start supplying resources to the *Rhizobia*. Secondly, it takes a few weeks for the number of *Rhizobia* bacteria to build up in the nodules and to start fixing appreciable amounts of N.

Hence, it can take a few months before the clover-*Rhizobia* symbiosis is becomes fully functional and productive. In the meantime the sward can go through a period of being N deficient and showing all the signs of N deficiency such as low production, brown or purplish tips on leaves and a strong propensity for producing seed-heads. The extent of this will depend on how inactive the *Rhizobia* bacteria are in the first place. The impact can be quite small in some fields where N inputs have been relatively scarce and more severe in other fields.

Once the *clover-Rhizobia* symbiosis becomes fully functional these clover swards should remain highly productive for the following four or five years. When converting over to clover-based swards by promoting the clover in existing swards it is necessary to be prepared to accept some degree of a setback to pasture production for a while. This setback might be relatively severe for a few weeks. In some instances it might take a whole growing season for the clover to become fully productive. However, after a month or two the clover should be making an increasing contribution to soil N supply and sward productivity.

Promoting clover in existing swards combined with over-sowing
Swards that contain a lot of old clover will benefit from an injection of new clover cultivars to make them fully productive. This can be achieved quite easily and at low cost by over-sowing these

swards. These swards can be brought into the over-sowing rotation in due course; i.e. where 20% of the farm is being over-sown each year on a five year rotation.

The first step in promoting old clover in swards is to check soil fertility, particularly lime, as these swards can sometimes be quite run down. Over-sowing can then be carried out as outlined above. One of the advantages of over-sowing into an existing clover sward is that these swards tend to be more open. Howeve r, a big advantage is that when fertilizer N is withheld, the old clover will generally start fixing N more rapidly than the new seedlings. In this way the sward does not take much of an initial setback while the new seedlings will grow to make the sward highly productive in the longer term.

Using pelleted clover seed under such circ u mstances might be advantageous, particularly where the soil pH is on target or lime has been applied. The pellet contains *R h iz o b ia* bacteria and the introduction of new *Rhizobia* might be beneficial in the same way as the introduction of the new clover cultiva rs, particularly if the sward has been very run down.

Herbicide use and clover survival

Inappropriate use of post-emergence herbicides such as CMPP on reseeds will lead to the rapid disappearance of clover and this has been dealt with in more detail in section 3.4. (Weed control in d i rectly reseeded swards) Another problem is sp raying for docks. There are a number of dock sprays that are sold on the basis that they do not harm clover. We have tested a number of these sprays and have found them to do far more harm to the clover than the d o c ks. As things stand there is no herbicide, clove r - safe or otherwise, that we would recommend for use on established swards containing clove r. The issue of controlling docks in clove r - b a s e d s w a rds is dealt with in section 4.6. (Controlling docks and other weeds in grassland).

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3.7. Converting the farm over to grass-clover swards

Three ways of increasing the clover content of swards have been outlined in the previous sections. In the process of converting a farm over to clover, all three of these methods should be employed. If tillage land is being converted or if grass-to-grass reseeding is being conducted on the farm because swards are rundown and infested with troublesome weeds, incorporating clover during direct reseeding obviously has a role. However, direct reseeding is likely to be the least important of the three methods. The most cost-effective method is simply managing up the clover content of existing swards. This means cutting back on fertilizer N on a portion of the farm and taking an initial hit to pasture production on this area during the first year. This is not an insurmountable problem but it requires planning in order to avoid generating a deficit of feed supply on the farm.

Take, for example, a dairy farm of 140 acres (57 ha) stocked at 0.8 LU per acre (2.0 LU/ha) and receiving fertilizer N input of 140 units per acre (175 kg/ha) (Table 9). An initial target can be to convert 40% of the farm during the first year. This can involve a combination of identifying swards with reasonable clover contents and over-sowing other paddocks after first-cut silage. In this case it is assumed that 20% of the farm has reasonable clover and can be upgraded by management. Another 20% is over-sown after first-cut silage. The upgraded 20% receives two applications of 23 units N per acre in spring and no more N from April onwards. The 20% over-sown receives 23 units N per acre in February and 92 units per acre in April for first-cut silage. This is over-sown after harvest with 2 kg clover seed per acre and receives slurry but no fertilizer N for the rest of the year.

Production on the upgraded and over-sown parts of the farm will be relatively low during the first year. To compensate for this, fertilizer N input on the other 60% of the farm is increased to 170 units per acre. In this way, pasture supply is kept in line with requirements during the first year of conversion. Overall, fertilizer N input during year one remains similar to the baseline year.

Table 9. The stepped conversion of a farm to clover-based swards

Farm divided into five equal blocks

	20%	20%	20%	20%	20%	Farm Average
Baseline	**Fertilizer N (units/acre)**					
Fert. N	140	140	140	140	140	140
Year 1 Fert. N	Upgrade grazing 46	Silage+ over-sow 115	Grazing 170	Silage 170	½ grazing ½ silage 170	135
Year 2 Fert. N	Clover grazing 46	Clover grazing 46	Silage + over-sow 115	½ over-sow ½ reseed 125	Silage 170	100
Year 3 Fert. N	Silage+ over-sow 92	Clover silage 92	Clover grazing 46	Clover grazing 23	½ over-sow ½ reseed 105	72
Year 4 Fert. N	Clover grazing 46	½ grazing ½ silage 69	Clover silage 92	Clover silage 92	Clover grazing 23	64

In year two 40% of the farm has reasonably good clover. This is used for grazing and receives a total of 46 units per acre for the year. Good production from the clover should be seen during the second year. Thirty percent of the farm is targeted for over-sowing after silage. This receives 115 units per acre similar to the over-sown silage ground in the previous year. Another 10% of the farm is reseeded during July. This is grazed during the spring and summer and receives 130 units per acre during the year. It is burned off in mid-June, grazed, cultivated and reseeded by mid-July and is back in the grazing rotation by the end of August or early September. It receives no fertilizer N after establishment. The remaining 20% of the farm is used for first-cut silage followed by grazing and receives 170 units per acre during the year.

Overall, average fertilizer N input on the farm in year 2 is 100 units per acre. This represents a 40% reduction compared to the baseline or a saving of €2,300 in fertilizer N. However, reseeding 10% of the farm at €150 per acre costs €2,100 and over-sowing 30% costs €1,200. These costs out-weigh the saving in fertilizer N. They

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also highlight the disadvantage of introducing clover by reseeding. If all the clover was introduced by over-sowing the saving in fertilizer N would more than cover the costs of over-sowing. In this case it must be assumed that some reseeding was necessary because of run-down swards and would have been conducted as part of routine farm practice.

In year three, up to 80% of the farm is under clover. This is mostly well established but there was also some degree of failure in previous years with poor establishment in some paddocks. These paddocks are identified and 20% of the farm under clover is over-sown again after first-cut silage using a rate of 1 kg clover seed per acre during year 3. Of the 20% of the farm not under clover, 10% is over-sown after silage and the other 10% is cultivated and reseeded during June and early July, similar to the previous year. Total fertilizer N use is 72 units per acre and is compatible with REPS. Total saving in fertilizer N compared to the baseline is 68 units per acre, which is worth €3,950. Reseeding costs in year three are €2,100 and over-sowing costs €950, because two-thirds was over-sown at the lower rate. Saving in fertilizer N during year three more than covers the cost of reseeding and over-sowing.

In year four the whole farm is under clover and some of these swards are well developed and highly productive. Low inputs of fertilizer N are needed for grazing and fertilizer N input for first-cut silage is reduced by 23 units per acre compared to that applied to grass-only swards. Fertilizer N use in year 4 is 64 units per acre, down 76 units per acre compared to the baseline. This represents a saving of €4,250. Twenty percent of the farm is over-sown at the low rate costing €560. Hence, the net saving in fertilizer N is almost €3,700. In poor grass-growing years, there is a fair degree of flexibility to increase fertilizer N input and still remain within the REPS limits.

At the beginning of this example it was pointed out that it was assumed that 20% of the farm had some clover that could be upgraded simply by management. For farms at this level of fertilizer N input and where some reseeding had been undertaken in the past, this is not an unreasonable assumption. In our experience, most farmers with moderately stocked farms are able to identify

areas with reasonably good clover, in some cases no more than 5 to 10% and in other cases well over 20% of the farm area. It depends to a large extent on the history of grassland management on the farm. These swards have to be viewed as a valuable resource. These can be upgraded at little cost and accrue substantial savings in fertilizer N in following years compared to other swards that need to be reseeded at relatively high cost. It is also clear that the cost of over-sowing has to be cut down to the bare essentials to make it worthwhile.

While the scenario outlined in Table 9 sets realisable targets, it is also our experience that farmers at moderately high stocking rates interested in going into REPS are able to get down to the REPS limits on fertilizer N input at a much faster rate than outlined in Table 9. This can involve jumping in at the deep end to a certain extent and enduring fairly tacky swards for a period of time. There is a period between cutting back on fertilizer N input and before the N fixation by the clover kicks in. Swards can show signs of N deficiency and start to head out more than normal. This is only a passing phase that should last no more than a few months during the first year of conversion. Sward nutritive value will improve in line with the clover becoming more prominent in the sward. Clover only becomes prominent when fertilizer N is withheld. This is one of the key management aspects of promoting and maintaining productive clover swards. More comprehensive details of management aspects of white clover-based grassland are provided in the next section.

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4. MANAGEMENT OF WHITE CLOVER-BASED GRASSLAND

The biggest difference between managing clover-based swards and fertilized grass-only swards is that white clover supplies its own N in the soil and therefore there is a much lower need to apply fertilizer N. Another difference is restriction on herbicide use for control of docks etc. However, for the most part, there is surprisingly little difference in the day-to-day management of clover-based swards compared to grass-only swards. Both swards are mainly composed of grass and annual grass growth dominates the pattern of pasture supply. Freedom from routine applications of fertilizer N from late April onwards is one less job on clover-based grassland farms.

Many aspects of the management of clover-based grassland are detailed in this handbook. Many of these aspects, such as target pasture covers, slurry management, fertilizer P and K use, etc. are exactly the same as we use for grass-only swards at similar stocking rates. Changing over to clover-based grassland is a bit like a six-year old switching from a tricycle to a bicycle. Both bikes operate on similar principles but, initially, it seems to defy logic that the bicycle can remain upright of its own accord. Experience has shown that there is little difference in the day-to-day management of swards, although there are some issues that are specific to grass-clover swards and these are outlined in this section.

We are often asked what is the biggest problem encountered in managing clover-based grassland. Issues such as bloat, ensilability or poaching damage during the winter are often suggested. However, we have not found these issues to be any greater a problem than they are with fertilized grass-only swards. We have had the same turn-out and housing dates and grazing days per year from clover-based grassland as from fertilized grass-only swards managed at the same stocking rate, and this is on a farm that is prone to poaching during wet conditions. One of the main questions that concerned us when setting up the clover swards at Solohead was how long we would be able to maintain productive clover swards over the following years. Another problem was how to control weeds such as docks in permanent grassland when most herbicides will eliminate or decimate the clover. We have been working on solutions to these problems and they are by no means insurmountable. Indeed, we started out at Solohead with a problem with docks and this has now been brought under complete control.

4.1. Maintaining the persistency of white clover in swards

Continually introducing new seedlings is a necessary part of maintaining white clover in swards. In southern Europe, in Mediterranean conditions where white clover originated, this happens naturally. Swards are very open and dominated by grassland species such as Italian ryegrass. Clover produces seed during the summer, the seeds germinate during the autumn rains and the seedlings have no problem surviving the short mild winters.

In colder more northerly areas such as in Denmark and Northern France, the clover content is maintained by rotating grass-clover swards with crops such as forage maize or cash-crops such as winter wheat. Typically maize is grown for around three years and the grass-clover is grown for three to five years. Very productive clover swards can be maintained under these conditions. Fertility that accumulates under the clover is taken out of the soil by the maize. The grass-clover is then re-established on soil with low N reserves. The clover dominates the sward under these conditions. By the time the clover begins to decline after four or five years, the sward is ploughed down for maize or other crops and the process is repeated.

In New Zealand grassland management tends to be similar to Ireland where grassland-based production is mainly based on grazing permanent pastures. However, unlike Ireland there is a long tradition of managing white clover in swards. This has lead to the build up of a large reserve of clover seeds in the soil in New Zealand. Seeds of most grassland species are able to survive for a number of years in the soil. These seeds germinate to produce seedlings whenever the opportunity presents itself. For example, if swards get damaged under grazing in spring, seeds germinate during the summer if there is enough rainfall, or during the autumn and become established before the winter. The big differences between Ireland and New Zealand are that (i) soils in New Zealand contain large reserves of clover seeds while the reserves in Ireland are virtually non-existent and (ii) conditions are more favourable for clover seedling growth and survival in New Zealand (short mild winters).

On the basis of these considerations we developed the concept of

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over-sowing as a low-cost method of introducing white clover seeds into grassland in Ireland. Approximately 20% of the farm is over-sown with clover seed each year on a five - year rotation. During the autumn and following spring, all swards are examined to see how well the clover is doing. Paddocks with poor clover contents are identified and ear-marked for first-cut silage. In general, swards that need to be over-sown will follow a clear rotation: Older swards will tend to have lower clover contents. However, this is not necessarily the case. Some swards will be productive for longer than others and in some instances it is necessary to over-sow these swards ahead of older swards with higher clover contents.

It is important that around 20% of the farm is over-sown each year. Skipping a year could potentially have long-term consequences. For example, in a year that is favourable to clover, all of the swards on the farm might look good and perform well. However, for every good year there is likely to be a bad one following on after a year or two. A sward with younger clover is likely to be more productive in a difficult year. Hence, over-sowing should be conducted as a matter of routine grassland management on the farm. The principle is to maintain a series of swards – each containing clover of different ages. This mitigates the risk of a widespread 'clover crash' in a year that is not favourable to clover growth.

4.2. Fertilization

Using low inputs of fertilizer N on clover swards is an important part of getting maximum economic benefit from the clover. For the most part, this means applying fertilizer N only during the spring. To describe our fertilizer N application strategy in a nutshell; we apply 23 units per acre (28 kg/ha) to the entire farm in February or March. Half of the farm is closed for first-cut silage. The silage area receives slurry and 70 units N per acre (86 kg/ha) in late March and early April. At around the same time the grazing area receives a second application of 23 units per acre (28 kg/ha). No more fertilizer N is applied for the remainder of the year.

In reality the strategy is more complicated than this. Grass growth and pasture supply can vary considerably from year to year. A

certain amount of flexibility is needed in fertilizer use to overcome this variability. Fertilizer N use is to a certain extent dependent on weather conditions, pasture covers etc.

It is generally recommended that around 23 units per acre (28 kg/ha) is applied to the whole farm at some stage during February or early March depending on stocking rate, location and soil type. Earlier applications are recommended for heavier stocking ra t e s, lighter soils and southerly locations and vice versa. On the grazing area, this may or may not be followed by a second application of 23 units per acre depending on stocking rate, pasture supply and the clover content of the sward. If there is low clover contents the second application might be needed to avoid crude pro t e in deficiency in the pasture during periods of high rates of pasture g rowth during late April and May. Under such circ u mstances the second application needs to take place at some stage around mid-April in anticipation of this surge in growth.

The fertilizer N application strategy used at Solohead is tied in to a large extent with slurry use on the farm and is usually dependent on pasture supply during the spring. Around two-thirds of the farm re c e ives slurry in late January. These are the paddocks that were closed up latest in the winter and have the lightest covers in spring. These will be the last paddocks to be grazed during the firs t grazing rotation in spring. Cows are turned out to grass by day as they calve from 1 February onwards and are out fulltime by early March. They will initially graze the one-third of the farm that did not receive slurry. This area receives 23 units per acre (28 kg/ha) of urea in mid-February in a blanket application. This area of the farm will be grazed off by the second week of March.

Plate 10. Slurry applied in spring is an important part of maximising efficiency of utilization of nutrients and lowering expenditure on fertilizers at Solohead.

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The two-thirds of the farm that got slurry in January receives 23 units per acre (28 kg/ha) of urea in early March. This area will be grazed between the second week of March and mid-April, when the first grazing rotation is completed. This means that there is usually at least a minimum of six weeks and up to eleven weeks between the application of slurry and grazing. Generally, the combination of rainfall and grass growth during this period ensures that the slurry is washed from the grass and the available pasture is fully acceptable to the cows. The slurry at Solohead is stored in outdoor tanks and therefore is quite dilute. The slurry is applied using an umbilical system. We have seen little or no change in cow behaviour when first allocated to paddocks that had received slurry in January. Nor have we seen any change in performance in terms of milk production and milk protein, which we would readily see if the cows were not happy with the pasture being presented to them.

By early March the whole farm will have received one application of 23 units per acre (28 kg/ha) of fertilizer N and two-thirds of the farm will have re c e i ved sl u r r y. A number of decis i o ns have to be made at this stage. In general, the paddocks for silage will already have been identified. If grass supply is very tight and it looks like we might need to graze the silage area for a second time, the whole farm, both silage and grazing are a s, will re c e i ve a second application of 23 units per acre (28 kg/ha) during March. This allows flexibility if it should be necessary to graze the silage area for a second time. The risk is if we apply 70 units per acre to the silage area and then end up grazing off these swards that much of the N will have been taken up by the grass and wasted by grazing. A less risky approach is to apply 23 units per acre to the silage g round during March. If conditions improve and we later re a l is e that it is not necessary to graze this area for a second time, it will receive slurry at a rate of 3000 gallons per acre in late March. This is followed by 46 units per acre (58 kg/ha) in early April for silage. Nothing is lost except time spent applying fertilizer.

On the other hand, if grass supply is plentiful during March the fertilizer N for silage is held off until early April when the 70 units per acre is spread all in one application. In this situation, which is typically the case, slurry is applied at a rate of around 3000 gallons per acre to the silage ground in late March. The fertilizer N is applied at a rate of 70 units per acre (86 kg/ha) in early April.

It is important that at least a week is allowed between applying slurry and the fertilizer N. If the slurry and fertilizer N are applied too close together there is the likelihood that the slurry will create t e m p o rarily waterlogged conditions in the soil, which caus e s denitrification and loss of some of the fertilizer N. The slurry is applied in late March. This allows at least six or seven weeks between application and harvest of first-cut silage, which takes place around the third or fourth week of May.

Fertilizer N applied to the grazing area during April will be taken up by the sward during the following four or five weeks, or less during periods of very rapid growth. There f o re, fertilizer applied in mid-April will continue to be taken up by the sward until well into the month of May. Under normal circ u mstances the growth of clove r should be up and running at this stage of the growing season and beginning to produce enough N in the soil to meet pasture requirements.

Table 10. Fertilizer N (units/acre) and slurry application strategy at Solohead. For simplicity, the farm is divided into six equal blocks

Date	Proportion of the farm						Farm average
	1/6	1/6	1/6	1/6	1/6	1/6	
Late-Jan	-	-	Slurry	Slurry	Slurry	Slurry	
Mid-Feb	23	23	-	-	-	-	7.7
early-Mar	-	-	-	23	-	23	7.7
Late-Mar	Slurry	23	Slurry	-	Slurry	-	3.8
Early-Apr	70	-	70	23	70	-	39
	Silage	-	Silage	-	Silage	-	-
Total fertilizer N applied by mid-April							58

As a simple rule of thumb no fertilizer N is recommended fro m mid-April onwards. In reality, at Solohead, some of the grazing area will receive 23 units per acre (28 kg/ha) in February or March and receive no more for the remainder of the year. This means that even when limited to a fertilizer N input of 72 units per acre averaged over the whole farm and a stocking rate of 0.9 cows per acre (2.2 c o ws/ha) we are able to keep some fertilizer N in re s e r ve for us e later in the year, if necessary, or not use it at all and save money in

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the process. It can be seen in Table 10, that around 58 units per acre (72 kg/ha) is applied by mid-April. This makes 15 units per acre (18 kg/ha) available for use later in the year if the need arises.

A reserve of 1 5 units per acre (18 kg/ha) might sound small but this is around 20% of the REPS fertilizer N allowance at 0.8 cows per a c re (2.0 cows/ha). In some ye a rs such as 2005, for exa m p l e , circumstances can combine to upset the normal course of events. E xceptional grass growth during the winter 2004/2005 did not favour stolon survival over the winter and cold weather during May d e l a yed clover development and slowed general pasture gro w t h until June. It is necessary to be pragmatic and flexible when reacting to such circumstances. What effectively happened was that conditions more typical of April were experienced during May.

Under these circ u mstances it is best to continue to manage the clover swards as if it was April and apply moderate rates of fertilizer depending on pasture supply. However, as soon as conditions begin to improve fertilizer N input should be stopped. These additional applications will rapidly push fertilizer N use up to the REPS limit. It has been pointed out above that clover can tolerate fertilizer N inputs of up to 170 units per acre (210 kg/ha) without any re a l impact on pasture production. There f o re, putting on additional fertilizer N can be good management practice under certain circumstances.

In years with exceptionally slow growth during the spring it may be necessary to graze some of the silage ground for a second time. For example, some silage paddocks may need to be grazed during late April or even early May. It is likely that these paddocks will have received two applications of 23 units N per acre (28 kg/ha) before being finally closed up for silage. These paddocks will then receive slurry followed by 70 units N per acre (86 kg/ha) and silage harvest date will be delayed until as late as the second week of June. If growing conditions are such that it is necessary to graze some of the silage area, it is also very important to push on grass production on the grazing area. This probably necessitates a third application of around 20 units per acre (25 kg/ha) of Urea or CAN to the grazing area in late April or early May.

This is not a problem from the point of view of clover survival. If conditions are unusually cold during the late spring, the clover will remain dormant until conditions improve. Under such circumstances it is very useful to have some fertilizer N in reserve, by not applying it all earlier in the spring.

In the majority of years, pasture growth during the spring will be sufficient and there will be no need for radical measures such as grazing the silage ground for a second time. This can mean that there can still be quite a large reserve of fertilizer N available for application, if necessary, later in the year. A period of slow growth can occur at any time of the year. It could be due to an unseasonably cold spell or drought conditions during the summer. For the most part, N supplied by the clover should be sufficient to meet requirements. However, if pasture supply is getting very tight, an additional booster shot of fertilizer N to some paddocks may help to lift covers back in line with targets. The paddocks to target for this application of fertilizer N are paddocks with older and declining clover populations that are likely to be due for over-sowing in the following year.

It is not necessary to apply fertilizer N to established clover swards during September to extend pasture supply into the winter. For well managed clover-based swards applying fertilizer N during the autumn is a waste of money. The clover is able to supply sufficient N to meet the requirements of the accompanying grass during the autumn and early winter. Generally, more than enough pasture can be ensured by extending out the rotation length in a planned way from late July. This means that the best time to apply fertilizer N, if necessary, to some paddocks is during August rather than September. The target is to ensure a pasture cover of between 600 and 700 kg DM per cow in early to mid-September (see below).

It has been pointed out above that slurry plays a very important role in meeting our requirements for N during the spring. A mixture of any remaining slurry and dirty water is applied to the silage stubble after first-cut silage. Dirty water is also applied to any area harvested for baled silage during July. Any remaining slurry and dirty water generated during the late summer is applied after grazing as the rotation is lengthened out to around 45 days. This

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dirty water is applied during late August or early September and generally there will be around six or seven weeks between application and grazing. These last applications ensure that the tanks are as empty as possible at housing.

Figure 8. Areas of the country where a response to sulphur is likely are indicated as shaded areas

Sulphur

More than 30% of Irish soils require fertilization with sulphur (S) for optimum production. Soils most likely to benefit from applications of S are sandy free-draining soils with low organic matter content. The best response to S occurs during the summer months. This is the time of year when no fertilizer N is being applied to clover swards. Sulphur-containing fertilizers that do not contain N are single-superphosphate, 9% P + 12% S, and sulphate of potash, 42% K + 18% S.

Areas of Ireland where deficiency of S is likely to be a problem are presented in Figure 8. In these areas it is advisable to apply urea + S for first-cut silage. An application containing around 16 units S per acre (20 kg/ha) will be sufficient to ensure optimum yields of herbage for first-cut silage. On the grazing area, singlesuperphosphate is an ideal fertilizer for clover-based grassland during the summer. Clover will benefit from both the P and S. One application of 16 units S per acre (20 kg/ha) should be sufficient to maintain a high level of pasture production. A bag and a half per acre (3.75 bags/ha) of single-superphosphate applied in May or June will meet this requirement.

Where input of P fertilizer is restricted due to high soil P concentrations (and REPS plans) sufficient S can be applied as one bag of sulphate of potash per acre (2.5 bags/ha) during May or June. Earlier applications are not necessary, as this is mostly a problem that occurs during the summer months. Earlier applications of sulphate of potash should be avoided because this fertilizer contains a high proportion of K and this could contribute to grass tetany (hypomagnesaemia) during the spring if there are already high levels of K in the soil.

Whether applying single-superphosphate or sulphate of potash it is important to tie this in with overall nutrient management planning on the farm. Silage swards often benefit from an application of K after harvest. Sulphate of potash can be used as a carrier for over-sowing clover seed applied after first-cut silage. If some fields are deficient in P, this can be remedied by an application of slurry in spring and an application of single-superphosphate during May. This entails the added benefit of meeting requirements for S at the critical time of the growing season.

It is important not to over-apply S where it is not required. An excess of S can cause deficiencies of selenium and copper in livestock. There is no reliable soil test for S. However, an accurate indication of likely deficiency can be gauged from samples of pasture. Pasture S content should be greater than 0.2% of DM and the ratio of N:S less than 15:1. If your farm fits the profile – light soils etc. – then it is a good idea to carry out your own test on the farm by applying a few runs of an S-containing fertilizer and judge the response relative to the surrounding area.

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4.3. Grazing management

Pasture covers are measured every week at Solohead. These are used to determine (i) when to leave the cows out full-time (day and night); (ii) level of concentrate supplementation during the spring; (iii) closing date for first-cut silage; (iv) the need to supplement during the main grazing season, if necessary (due to poor growing conditions, etc.); (v) the area to be removed as baled silage during July; (vi) the build-up of pasture during August and September; (vii) dates of closing swards for the winter; and (viii) winter growth and turn-out in spring. Pasture cover in conjunction with considerations such as ground conditions have a big influence in decision-making on the farm from week to week.

During the spring we also use a spring grazing allocation planner (Table 11). This planner is used to estimate the area of the farm that can be grazed at the end of each week between turnout on 1 February and the end of the first rotation, which is planned for some date between 12 and 19 April. It is simple to use and gives a second reference point with which to cross-check pasture cover measurements and the rate at which the supply of pasture is being allocated out to cows during the spring.

The grazing allocation planner gives a rough idea of how much of the farm should have been grazed at the end of each week. If the target is greatly exceeded, it means that cows might have to be kept in at night and more concentrate and silage fed. It we are below target we can push the milking cows out grazing fulltime, cut back on concentrate, cut out silage and take a ‘wait and see’ approach to fertilizer N usage. If there is plenty of pasture available during March, the application of fertilizer N is held off until a later stage when it might be needed if conditions deteriorate. It can be seen in Table 11 that 29.5% of the farm is targeted to be grazed by 15 March. This roughly coincides with the area of the farm that did not receive slurry during late January or early February. It can also be seen that grazing pressure, in terms of cows calved, is relatively light during February, when cows are in at night, and increases substantially during March. Hence, around two-thirds of the farm is needed for the second half of the first grazing rotation.

Table 11. Spring grazing allocation planner used at Solohead

Date	Proportion of cows calved	Proportion of farm allocated each week	Cumulative proportion of farm grazed off at the end of each week
	(%)	(%)	(%)
01 Feb	2	0.1	-
08 Feb	12	0.9	0.1
15 Feb	28	2.1	1.0
22 Feb	50	3.7	3.1
01 Mar	70	10.5	6.9
08 Mar	81	12.1	17.4
15 Mar	88	13.2	29.5
22 Mar	92	13.8	42.7
29 Mar	95	14.2	56.4
05 Apr	97	14.5	70.7
12 Apr	99	14.8	85.2
19 Apr	100	-	100.0

Achieving target covers in early September is the single most important objective in the grass-growing season. Achieving this target is of central importance in determining the amount of pasture available for grazing during the autumn and winter and again at turn-out during the spring. This is dependent on grassland management decisions made during late July and August. While this period is often seen as a free-wheeling time of year when grass supply and ground conditions are generally ideal for grazing, there is no room for complacency when it comes to achieving target covers. Bad decisions, such as taking out baled silage during August, can have long-term consequences for pasture supply. Bad decisions in August can have knock-on consequences right through until the following April or May.

Pasture cover is measured using a New Zealand (Genquip) rising plate-meter. Measurements of compressed pasture height are converted to available pasture (kg DM/ha) by deducting 5 cm from the measured pasture height. Each cm of pasture above 5 cm is allocated a value of 240 kg DM. For example, for a sward with a compressed height of 12 cm, 5 cm is deducted to allow for residual stubble. This leaves 7 cm of available pasture or 1 680 kg DM/ha. An alternative equation can be used: (height (cm) x 240) – 1200, to give the same result.

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Table 12. Target pasture covers (kg DM per cow) during the year

Date	Cover	Date	Cover	Date	Cover
04 Feb	370	19 May	200	01-Sep	550
11 Feb	355	26 May	200	08-Sep	600
18 Feb	340	02 Jun	205	15-Sep	650
25-Feb	325	09 Jun	210	22-Sep	650
03 Mar	310	16 Jun	215	29-Sep	615
10 Mar	295	23 Jun	220	06-Oct	580
17 Mar	280	30 Jun	225	13-Oct	540
24 Mar	265	07 Jul	230	20-Oct	495
31 Mar	250	14 Jul	240	27-Oct	450
07 Apr	240	21 Jul	250	03-Nov	405
14 Apr	230	28 Jul	300	10-Nov	350
21 Apr	220	04 Aug	350	17-Nov	300
28 Apr	210	11 Aug	400	24-Nov	245
05 May	200	18 Aug	450	01-Dec	190
12 May	200	25 Aug	500	-	-

The target covers in Table 1 2 are presented in terms of covers per LU because this allows for interpretation on farms with differe n t stocking ra t e s. For example, if the target cover during May and June is around 200 kg DM per LU, this equates to a target cover per ha of (i) 500 on a farm stocked at 1.5 LU per ha and 40% of the farm closed for first-cut silage; and (ii) 1000 on a farm stocked at 2.5 LU per ha and 50% of the farm closed for first-cut silage. Different parts of farms can also be stocked at different rates. For example, the area around the milking shed is generally stocked at a higher rate than parts of the farm used for replacements or beef cattle. There f o re, there will be different adjustments for stocking rates needed on these various portions of the farm while the target cover per LU remains the same.

During the main grazing season pasture available for grazing (not closed for silage) is divided by the number of cows to give pasture cover per cow. During the spring, when only the milking cows are at grass, the amount of available pasture is divided by the number of cows out grazing + the total number of cows divided by two. For example, for a total herd size of 60 cows with half the herd, or 30 cows, out grazing on 25 February, available pasture is divided by 45 ((30 + 60) ÷ 2) to give pasture cover per cow. Suppose the cows a re getting 4 kg concentrate and 3 kg silage DM at night, this means that we expect the cows to eat 8 kg pasture DM during the

day giving a total intake of 1 5 kg DM per head per day. Our target cover on 25 February is 325 kg DM per cow. This divided by 8 kg DM per cow means that we have 40 days of grass ahead of us, assuming no growth. This means that we have enough grass to stay g razing by day only until 6 April, in the unlikely event of no growth. If our covers are above target, it means that we can leave the cows out at night and stop feeding silage.

Plate 11. The clover content of swards can represent around 5 to 10% of pasture DM during April.

A question that often comes up is whether there is any difference in topping clover-based swards compared to grass-only sward s. The experience at Solohead is that there is no difference. The grazing a rea, which re p resents around half of the farm during late April, May and June, is topped at some stage during May or early June. A second round of topping takes place during late June and July. All topping is stopped by mid-July. High clover contents during the second half of the grazing season make it easier to graze out s w a rds to lower post-grazing re s i d u a ls. Tight grazing during the period from turnout in spring right through to mid-July will favour the clover content of swards.

It can be seen in Table 12 that our target cover is 250 kg DM per

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LU on 21 July and that it increases by 50 kg DM per LU for each week from 21 July to the 1 5 September. Any surpluses that need to be taken out are baled by mid-July and all topping ceases. Covers are allowed to rise in line with the high rates of growth that we normally see on the clover-based swards at this time of the year. The clover is generally able to supply sufficient N and all that is needed is to allow the rotation length to increase to allow sufficient pasture to accumulate. Rotation lengths go from around 20 to 25 days in mid-July to around 30 days by mid-August and 40 days by mid-September, to around 50 days by mid-October and to around 70 to 75 days for the last rotation ending in early December (Table 13). Rotation length can be extended to around 45 days with grass-clover swards without causing a major reduction in sward quality. Research by INRA at Rennes in Brittany has shown that grass-clover s w a rds on a 42-day rotation had similar nutritive value as gra s s - only swards on a 28-day rotation during the autumn. The clove r content of the sward is at its highest during the autumn and this contributes to maintaining sward quality under long rotations.

It is very important to be on target during late July. From then onwards covers are allowed to increase in line with growth rates. If growth rates are above average, the covers can go well above target. This can mean grazing very heavy covers for a period during late August or early September. For example, if our average cover runs to 700 kg DM per LU. This is an ave rage cover of 1400 per ha, assuming a stocking rate of 2.0 LU per ha. This means that our pre-grazing cover can be around 2600 kg per ha. In fact we have often ended up grazing cove rs of 3000 kg per ha or more during late August or early September.

Table 13. Rotation lengths during the grazing season

Rotation lengths	Days
Mid-May to mid-July	18 to 24
Rotations ending mid-August	30
Rotations ending mid-September	40
Rotations ending mid-October	50
Late rotation ending in early December	75
First rotation in spring (e.g. 30 Jan to 15 April)	up to 75
mid-April to mid-May (silage ground out)	75 to 18

This is part of the trade-off in being able to graze into late November or December. If we did not graze heavy covers in late August or early September, it would mean that the cows would be housed and fed silage earlier in the autumn/winter. We estimate that the impact of heavy covers in late August or early September on milk and solids output is far less that the potential impact of earlier housing and feeding silage later in the year. Keeping cows out at grass is also far more cost-effective than earlier housing.

The only exceptions to this are swards that have been over-sown with clover seed during the summer. It is important that high covers are not allowed to build up on these swards. The rotation length on the over-sown swards should be held at around 24 days until well into September when growth has slowed sufficiently so as to not pose a major threat to the new seedlings.

Plate 12. The clover content of pasture maintains high nutritive value when grazing high covers during the autumn

The main point is that we will take no action to lower our covers, such as taking out silage etc., if they start to run ahead of target in the period from late July to mid-September. It is seen as far too big a risk. It must always be remembered that from 21 September

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onwards, the period of darkness at night is getting increasingly longer than the period of daylight. Pasture needs light to accumulate. Even if covers are very high, it is unlikely that growth rates will be sustained during September and pre-grazing covers will inevitably begin to decline. If the rotation length is long enough (40 to 50 days), covers per LU should remain above 600 for the month of September. In this case we are well set up for the autumn, winter and following spring. If covers are not up to target by early September rotation lengths can spin down very rapidly during late September, October and November.

If covers are below target in mid- to late September there is very little that you can do about it. Applying fertilizer N will be no more than a case of slamming the door after the horse has bolted. From the autumnal equinox (21 or 22 September) onwards, the response to fertilizer N is usually very poor. This emphasises the importance of not ending up in that situation. It is better to risk having high covers in late August than no cover at all in early November (assuming that ground conditions will allow grazing during November and early December). It could happen that bales made in late August can be fed back to cows during November. This is a high-cost and time-consuming method of turning a reasonably high quality feed into a lower quality feed that will have a negative impact on animal performance.

This brings us back to grassland management during late July and August. Grass grows grass, so it is important to increase rotation length and to let covers build up. This should happen once no surpluses are removed and all topping is stopped. However, drought or exceptionally wet conditions during this period can negatively impact on growth. In the case of a mild drought it is usually better to do nothing until conditions improve. Lost production can often be made up by compensatory growth that occurs after the rain returns. However, if covers are well off target by the third week of August it is probably necessary to take action.

If you have any fertilizer N left in reserve this is a good time to apply it. The ideal paddocks to target are those planned for over-sowing in the following year. Fertilizer N tactically applied to 10 or 20% of the farm at this time of the year can often be sufficient to

bring cove rs back on target by mid-September. It must be emphasised that this should only be necessary in about one year in five. Routine applications during August will generally be a waste of money.

With good management during August, it is most likely that high covers will be more of a problem than low covers during September. One disa d vantage associated with very heavy cove rs during the autumn and early winter is the risk of not getting all the swards grazed down to target before closing – especially when there are very wet conditions during the autumn. The target is to graze out to an average cover of around 170 to 200 kg DM per cow (350 to 400 kg DM per ha). This is an important component of maintaining high clover contents in swards during the following year. If some paddocks remain ungrazed during the winter due to wet conditions during the autumn, it is important to get out early and graze them during February.

The loss of stolon over the winter and the fact that the clover does not start to grow until April makes the clover very vulnerable to competition from the grass sward during February, March and April. The excessive loss of clover stolon over the winter could result in the total elimination of the clover from the sward. One way to prevent this situation is to graze out well during the autumn and early winter. This allows light down to the dormant clover at the base of the sward and this promotes stolon survival over the winter. This practice promotes clover survival and high quality grass swards in the following growing season.

4.4. Making silage from clover-based swards

F irst-cut silage will yield around 35% more silage per acre for virtually the same input costs as second cut. It makes economic sense to make all or most of the winter silage requirement as first-cut silage. This means maximising stocking rate on the grazing area during April and May and harvesting as large an area as possible for first-cut silage. It has been shown in Table 10 above that almost two-thirds of N applied to the clover-based swards at Solohead is t a rgeted towards maximising yields of first-cut silage. This N is being applied at a time of year that ens u res maximum

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re sp o ns i veness in terms of herbage production. High yield of herbage per acre for silage is important because contractors usually charge for harvesting silage on a per acre basis.

Plate 13. Clover-based grassland produces similar yields of first-cut silage to grass-only swards receiving higher inputs of fertilizer N. Making most of the silage requirement as first-cut lowers cost of silage per tonne in the pit.

At a stocking rate of 0.8 LU per acre (2.0 cows/ha; the REPS limit) it is possible to make all of the silage required as first-cut during M a y. This means closing up around 50 to 55% of the farm for silage harvested during May. One problem with this is that if all of this area is harvested at once a very large area of ground is being brought back into the grazing rotation during June. This can mean that pasture supply can get very tight as growth declines during early to mid-June with large amounts of pasture coming into the rotation in late June and early July. While we target to harvest 55% of the farm in total during May, around 10% is taken out as an early harvest during the first or second week of May at the latest. It is important that this early harvest is taken in early May. Taking the h a r vest in early May means that the after-grass can be bro u g h t back into the grazing rotation during the critical period in early June. This ens u res pasture supply stays in line with re q u i re m e n t s during June. The remaining 45% is taken out during the third or fourth week of May.

While we normally plan to get the whole farm area, silage and grazing ground, grazed off before mid-April, this does not usually happen except in years with exceptionally low spring growth. Up to 10% of the farm can remain ungrazed at the end of the firs t rotation. This will generally be the parts of the farm closed up last in the winter. This ground is allowed to run on and is harvested for silage during the first week of May. It is not ideal but clover is able to tolerate this practice reasonably well. Paddocks such as this can be over-sown with clover and it is highly likely that soil moisture conditions will be favourable. This helps spread the risk associated with over-sowing, particularly if soil conditions happen to get dry towards the end of May.

At Solohead there is no planned second cut from the clover swards. This means that the whole of the farm area is available for grazing from June onwards and we generally run into a surplus of pasture during July. When necessary, some baled silage is harvested to bring pasture covers back in line with target. This is harvested in mid-July at the latest and can often have high clover content. This is given a 24 to 48-hour wilt before baling. Harvests are relatively light and ground and weather conditions are generally conducive to getting a good wilt during July. Wilting overcomes any difficulties in ensiling t h is high-clover herbage. Indeed, this wilted clover-silage is g e n e rally of very high nutritive value and is very acceptable to livestock, with high intake characteristics.

4.5. Bloat

It is not very easy to write about bloat based on our experience at Solohead. After seven ye a rs of managing clover-based swards we h a ve never encountered a case of bloat that needed tre a t m e n t . Indeed, we have seen more cases of mild bloating in cows grazing fertilized grass-only swards on frosty mornings in April and May than on clover-rich pastures during July and August. This does not mean that we do not take heed of this issue. Researc h e rs in Brittany, who have many years more experience with clover-based swards, report that cases of bloat might not occur for many years and suddenly a cow can be found dead – out of the blue. Therefore, while we are not unduly concerned about this issue, it is one that we are aware of and take steps to avoid.

Under normal circumstances large volumes of gas are produced in the rumen as a consequence of normal rumen digestion. This gas escapes from the rumen by a process known as eructation (mild belching) on a regular basis and does not normally cause any problems. 1-lowever, clover contains substances that cause the gas to get trapped in bubbles a bit like the bubbles formed by washing up liquid on the surface of water. These bubbles trap the gas and slow down the rate at which it escapes from the rumen. This does not normally create much of a problem. 1-loweve r, if the cow is ve r y hungry and gorges on clover-rich pasture, a lot of gas can be produced in a short period of time. The rate of formation of gas bubbles can exceed the rate at which the gas can escape from the rumen. The cow then starts to swell up. Pluronics bring about the rapid dispersal of the bubbles.

The biggest risk of bloat is when cows are grazing swards that contain a high proportion of clove r. There f o re, the most likely period of risk is during the late summer and early autumn when clover can make up to 40% of the sward DM. It is important not to allow the cows get too hungry before being allowed in to gra z e such pastures.

One tactic used at Solohead is to allow the cows three gra z i n gs from a two-day paddock. After the third grazing, the cows are switched into the next clover-rich paddock in the rotation for one grazing during the daytime when it is easier to keep an eye on the cows. The cows will tend to graze the clover which is mostly located in the upper laye rs of the sward. 1-loweve r, these cows are not excessively hungry because they have not grazed out the previous paddock and, hence, there is little risk of gorging and bloat. These cows are then sent back to graze out the previous paddock during the night time. These cows will be re l a t i vely hungry on the following morning but then they are being allowed into a clover- rich paddock that already has one grazing re m oved from it. That single first grazing lowers the clover content sufficiently to minimise the risk of bloat for the hungry cows.

Plate 14. Care is needed when introducing livestock to clover-rich swards during the late summer and autumn to avoid bloat.

Another factor that could account for the absence of problems with bloat at Solohead could be the grassland management during the late summer and autumn. Rotation lengths are extended to 30 days by mid-August and 40 days by mid-September. While these swards are rich in clover, the grass component is generally getting strong. Slightly lower digestibility grass is balanced by the high digestibility clover to provide a diet that gives unrestricted animal performance. However, the bulky grass component of the sward helps to fill the rumen to the extent that it has a moderating effect on the rate of intake and pre vents the cows from gorging thems e l ve s. Obviousl y cows are much more likely to gorge if they are presented with low covers of highly digestible clover-rich pasture than covers of pasture in excess of 2000 kg DM per ha. Building covers during August has the spin-off benefit of mitigating the risk of bloat.

Cows are removed from paddocks twice per day for milking. This facilitates the switching back and forth between paddocks outlined a b ove. This approach is probably less feasible for cattle and replacement stock. Where cattle are being paddock-grazed, i.e. left in the same paddock for periods of around seven days before moving on to the next paddock, it is important to be conscious of the risk of bloat during the late summer and autumn.

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4.6. Controlling docks and other weeds in grassland

One of the biggest reasons for incurring the expense of reseeding is the deterioration of sward botanical composition due to loss of perennial ryegrass and ingress of troublesome weeds such as bent grasses and docks. Repeatedly harvesting silage off the same field from one year to the next causes the loss of perennial ryegrass and exposes the sward to invasion. Bent grasses are twice as efficient at competing for available soil N as perennial ryegrass under low soil lime status, whereas rye g rasses are more competitive at recommended soil lime status (pH = 6.5 to 6.8). Docks are promoted by high soil K status. Cattle slurry contains high levels of K. Excessive applications of fertilizer K in addition to recycled cattle slurry will promote docks at the expense of the existing perennial r ye g ra s s, particularly where the sward is weakened by re p e a t e d h a r vests of silage. There fo re, soil testing and balanced K fertilization is important to control docks while also avo i d i n g problems such as grass tetany.

The best way to avoid problems with weeds such as bent grasses and docks is not to create conditions that cause them in the first place. This means getting the basics of good gra s sl a n d management right before having to resort to more drastic measures such as herbicide use and reseeding. In so far as it is possible silage ground should be alternated with grazing from year to year. This is easier said than done, but once the problem is recognised a wide range of options can be cons i d e red. For example, if silage is normally harvested on an outside farm and replacement stock and beef cattle are kept on the home farm during April, May and June, the replacement stock and beef cattle could be moved to the out- farm in spring and silage made at home. Alternating silage and g razing ground from year to ye a r, or within ye a rs, will gre a t l y lengthen the useful lifespan of a sward and lower reseeding costs. Maintaining lime status will keep out bent grasses from swards in general, and rushes from wet ground.

Plate 15. Docks can be a very difficult weed to control in grassland.

Docks are a problem in grassland because there is no single remedy that can effectively eliminate them from swards. The way to beat d o c ks is by a war of attrition where the docks are re p e a t e d l y attacked from a number of different angles. In drastic situations the only solution might be to burn off the sward with glyphosate and start again. Steps to avoid docks in reseeds have been outlined in section 3.4. The next step is alternating silage and grazing ground and balanced K fertilization.

In clover swards sp raying with herbicides will seriously knock back the clove r. There fo re, herbicides such as Dox s t a r, Grazon etc. (Ta b l e 14), which are reasonably effective against established docks, can be used when you are not too worried about killing out the clove r. One opportunity to do this is during the autumn prior to ove r - sowing a sward. The sward can be sp ra yed with herbicide such as D oxstar (Flurox y py r / t r i c l o pj). This will hit the docks and kill off the clove r. In the following spring this sward is then fertilized for f i rst-cut silage and over-sown with new clover after first-cut silage – using the higher seeding rate of 2 kg/acre. This approach is not g e n e raly recommended and should not become routine pra c t i c e . I nsofar as it is possible it is better to retain the old clover in s wards.

The final option and probably the best for keeping on top of low to

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moderate infestations of docks is spot-spraying. This can involve a number of different methods but it generally involves walking a round spraying herbicide directly onto individual dock plants or patches of docks. The method used at Solohead is a lance on a hose attached to a tractor-mounted sprayer containing a standard dilution of Doxstar.

For low to moderate infestations spot-spraying works out as cost-effective as spraying the entire field. The extra time and labour spent spot-spraying is more than compensated for by the saving in herbicide. Doxstar is used because it is reasonably effective against docks and won't damage the grass, although clover will be eliminated within the spot sprayed. This reduces the likelihood of burnt out patches in the sward compared with when broad-spectrum herbicides, such as glyphosate, are used. Once the clover is only killed out in isolated spots, it can readily re-colonise these patches through renewed stolon growth.

Table 14. Herbicides for control of docks in established grassland

Chemical	Product	Comments (cost/acre)
CM PP-P	Com pitox, Duplosan, Optica	Will wipe out clover. €9 - €11. Short-term suppression.
Dicamba/CM PP-P	Foundation, Kildock	Controls both dock species. Will wipe out clover. €10 - €12. Medium-term suppression.
Asulam and sulfonyl urea products Amidosulfuron	Alulox Prospect Eagle	May have a negative effect on grass and clover. €10 - €21. €30 - €35. Medium-term suppression.
Dicamba/Triclopyr Fluroxypyr	Bandock, Garlon, Grazon, Starane,	Wide spectrum control including docks and dandelions. Will wipe out clover. €20 - €45. Long-term suppression
Triclopyr/Fluoxypyr Triclopyr/Fluoxypyr Clopyralid	Doxstar Pastor	Wide spectrum, Controls both dock species. Will wipe out clover. €20 - €45. Long-term suppression.

Another approach is to use small volumes of diluted glyphosate. This can be applied using commercially available lances or by home-made ‘squeezy bottle’ applicators. Only a few small droplets of concentrated glyphosate are required to kill a dock plant, so care is needed to avoid excessive rates of application. Once the glyphosate makes contact with a leaf, it is translocated within the plant and down into the roots to give an effective kill. This might not be immediately apparent. Glyphosate can be slow acting but it is deadly to docks. It could be a few weeks or a month before the extent of the kill becomes apparent. The idea of spot-spraying sounds far more daunting than it is to actually do it. It is also a low-cost and, importantly, an effective way of keeping docks under control.

4.7. Pests and Diseases

There are no major pests and diseases of clover in Ireland in the same way as there are no major pests and diseases of the grass component of the sward. Pigeons can sometimes consume a considerable amount of clover in early spring in fields near trees but this is not a widespread or serious problem. Horseshoe weevils get their name because they make horse shoe shaped bite marks on clover leaves. This pest is a problem in New Zealand. In Ireland, a parasitic wasp keeps populations under control. Wasps from Ireland have been released in New Zealand as a means of biological control.

Plate 16. Horse shoe weevil bite marks on clover leaf.

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