RESEARCH TOPIC REVIEW: Grass clover ley species and variety selection and management

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1. Scope and Objectives of the Research Topic Review:

The objective of the Grass Clover Ley research review is:

1. To identify all the relevant research undertaken
2. Collate the results of the research
3. Draw on farm and commercial experience
4. Summarise the practical implications of the research for organic farming
5. Facilitate access to the results of research to advisers in a form which allows easy transfer to farmers

Issues and information covered:

1. Grass clover leys for grazing, conserving and fertility building
2. Characteristics and role of different species and varieties
3. Selection of species, varieties and mixtures to suit the site and purpose of the crop.
4. The use and role of herbs in grass clover mixtures is considered elsewhere in the PAC Res Research Review "The role and management of herbal pastures for animal health, productivity and product quality"

2. Summary of Research Projects and the Results

2.1 Grass & clover species

There is a very substantial body of literature and practical experience on the relative merits of the range of grass and legume species which are adapted to the UK, albeit most of the published material relates to non-organic situations. Standard texts include the following books:

Frame, J. (1992) *Improved grassland management*. Farming Press, Ipswich. ISBN 0 85236 246 3

Frame, J. (2005) *Forage Legumes for Temperate Grasslands*. FAO, Rome and Science Publishers Inc, Plymouth. ISBN 92-5-105043-0

Frame, J., Charlton, J.F.L. and Laidlaw, A.S. (1998) Temperate Forage Legumes. CAB International, Wallingford. ISBN 0 85199 214 5.

Hopkins, A. (1999) *Grass: its production and utilisation* (3rd Edn.). Blackwell Scientific Publications, British Grassland Society. ISBN 0 632 05017 9

Sheldrick, RD., Thomson, DJ., Newman,G (1987) *Legumes for milk and meat*. Chalcombe Publications, Canterbury.

Spedding, CRW., and Diekmahns, EC. (1972) *Grasses and legumes in British agriculture*. Bulletin No 49, CAB. 0 85198 016 3

Increasingly, technical material is also available on the web, and FAO has a very useful web-based database of profiles of hundreds of grass and legume species: http://www.fao.org/ag/AGP/AGPC/doc/GBASE/Default.htm.

The descriptions of legume species by John Frame in this database are extremely comprehensive and will be very useful for advisers. At the end of each of these very detailed profiles the author helpfully lists the main attributes and main shortcomings of the species in question. Unfortunately the material by Alain Peeters on the common temperate grass species found in north-west Europe is not as comprehensive.

Grass species

The main species of grass used for agricultural purposes in the UK are perennial ryegrass, Italian ryegrass, hybrid ryegrass, timothy, cocksfoot. Another group of grass species are sometimes used in specific circumstances: meadow fescue, tall fescue, red fescue, smooth-stalked meadow grass. A third group of species have limited agronomic merit but are sown for amenity or environmental conservation purposes: Common bent, Crested dogstail, Yorkshire fog. The main characteristics of the main agricultural grass species are shown in Appendix 1.

Perennial ryegrass is very well suited to the mild climatic conditions of maritime north west Europe, but is too susceptible to winter kill for Scandinavian and continental climates, where timothy and meadow fescue are more commonly used. Although perennial ryegrass has been criticised as being more appropriate for intensive high N systems than for organic systems, it is undoubtedly the most suitable species for ley farming in temperate maritime conditions, given its ease of establishment, yield potential, persistence, and quality characteristics. The lower mineral content observed in perennial ryegrass (Swift et al, 1990; Younie et al, 2001) may be simply a dilution effect caused by its relatively high yielding ability and may be ameliorated by an appropriate choice of companion species in the seed mixture. Another reason for a continued reliance on the ryegrasses, particularly perennial ryegrass, is the very wide choice of varieties available, from early flowering erect varieties suitable for early grazing and cutting, to late flowering prostrate and persistent varieties suitable for long term intensive grazing management. There are currently over 70 varieties of perennial ryegrass in the NIAB Herbage Varieties Guide (NIAB, 2007). Eleven of these recommended varieties are listed on the organicxseeds web database as being available as organically grown seed.

Whilst there are very strong arguments in favour of the ryegrasses being the principal components of most mixtures for grass leys, the other species listed above do have significant attributes which should be exploited for specific situations. For example, where the sward is intended for primarily a cutting management, timothy should always be considered. Likewise, on dry sandy soils cocksfoot is a more suitable species than perennial ryegrass and should always be included in the mixture. Further discussion of seed mixtures can be found in Section 2.3 below.

Herbage legume species

The main herbage legume species used in the UK are white clover, red clover, alsike clover, lucerne and sainfoin. These species can be categorised by growth habit, and this essentially dictates the agronomic situation for which the species is most suited. White clover is stoloniferous and the other species have an upright growth habit, growing from a crown. This latter characteristic makes these species very well adapted to cutting management but much less suitable for grazing management than white clover, and also less persistent. Lucerne and sainfoin also have more stringent requirements in terms of soil type. The main characteristics of these legume species are shown in Appendix 2.

As suggested above and in Appendix 2, white clover is the most appropriate and widely used forage legume for organic farming systems in temperate maritime climates, because of its adaptability to a range of management and soil fertility conditions. It is persistent, tolerant of a reasonably wide range of soil pH and drainage conditions, and can be used for management regimes ranging from continuous sheep grazing (for which small-leaved varieties are most suitable) to lax defoliation, including cutting (for which larger leaved varieties are most suitable). Red clover and lucerne are appropriate only where short-term swards, specifically for cutting management, can be fitted into the farming system, but they do have greater yield potential than white clover under cutting management.

White clover, red clover and lucerne were compared in a major EU-funded research project, LEGSIL ('Legumes for silage in low input animal production systems'), which was completed in 2001 (Wilkins, 2001, Halling et al, 2001). In addition to these three species above, two other legume species were compared in these trials; birdsfoot trefoil (*Lotus corniculatus*) and galega (*Galega orientalis*). The five species were grown as pure swards or in mixture with meadow fescue at four organic sites in Finland, Germany, Sweden and UK. The UK site was at Trawsgoed, Aberystwyth. Meadow fescue was also sown alone in two additional treatments, without added N and with N applied at 200kgN/ha/ann as urine. Three cuts were taken per year.

In this project, red clover and lucerne yields were comparable to grass receiving 200kgN/ha. In a further statistical examination of data from this and other north European forage legume projects, Halling et al (2004) concluded that red clover and lucerne yielded on average about 2.5tDM/ha/annum more than white clover. Although at the UK LEGSIL sites there was little difference between pure stands of the legume and legume/grass mixtures, at other sites the inclusion of grass with the legume gave consistent increases in yield, as well as reductions in soil mineral N. In a practical organic situation the inclusion of grass in the mixture would also improve competitiveness against weeds. Mean yields across all sites were highest with lucerne, but the most consistent performance was obtained with red clover. Yields for white clover were lower but consistent across sites. Lotus had a low yield and low persistence, and galega failed to establish at the UK site.

The costs of producing silage from pure and mixed crops, apart from galega, based on UK results in the LEGSIL project, are shown in Table 1 below. Red clover silage consistently tends to have among the lowest costs of production per kg DM of ensiled material. Mixed grass-legume silages also tend to have lower unit costs of production than pure legume silages. In fact the differential between the cost of legume silages and fertilised grass silage will have increased significantly since these calculations were made, with the substantial increase in the price of N fertiliser in late 2007.

Table 1. Average Total Costs per kg DM of Silage for Organically-Grown Forage Crops (extracted from Doyle and Topp, 2002)

Silage Crop	Euros $(kg\ DM)^{-1}$
Grass[1]	0.118
White Clover	0.095
Red Clover	0.086
Lucerne	0.087
Lotus	0.097
Grass-White Clover	0.089
Grass-Red Clover	0.086
Grass-Lucerne	0.088
Grass-Lotus	0.092

[1] Grown conventionally, receiving 200kgN/ha/ann.

Estimates of the theoretical value of the silage, based on the nutritional value of the crop for dairy cows and the prices of purchased substitute feeds are presented in Table 2. For grass-legume silages, the values are presented for silages with low and high legume contents. The pure legume silages have the highest economic value, although as shown in Table 1 above, costs of production tend to be higher than for grass-legume silages. However, grass silage appears to have both the lowest economic value and the highest costs of production.

Table 2. Estimated Value per kg DM of Silage (extracted from Doyle and Topp, 2002)[1]

Silage Crop	Euros $(kg\ DM)^{-1}$
Grass	0.117
White Clover	0.142
Red Clover	0.139
Lucerne	0.131
Lotus	0.131
High legume content	
Grass-White Clover	0.129
Grass-Red Clover	0.132
Grass-Lucerne	0.124
Grass-Lotus	0.121
Low legume content	
Grass-White Clover	0.123
Grass-Red Clover	0.125
Grass-Lucerne	0.120
Grass-Lotus	0.120

[1]Ignoring any organic premium on milk

Relative to the estimated profits per hectare of grassland, Table 3 below presents the projected increase in profits per hectare from growing and ensiling forage legumes either as sole crops or mixtures with grass.

Table 3. Estimated percentage increase in profitability per hectare from growing and feeding a legume or grass/legume silage, relative to grass receiving 200kgN/ha/ann[1] (extracted from Doyle and Topp, 2002)

Crop	Percent	Ranking
White Clover	17.8	4
Red Clover	29.2	1
Lucerne	20.7	3
Lotus	8.8	10
High legume content		
Grass-White Clover	16.5	5
Grass-Red Clover	22.5	2
Grass-Lucerne	12.9	7
Grass-Lotus	6.9	11
Low legume content		
Grass-White Clover	11.7	8
Grass-Red Clover	16.4	6
Grass-Lucerne	9.7	9
Grass-Lotus	6.2	12
Grass[2]		13

[1]Ignoring any organic premium on milk
[2] Grown conventionally, receiving 200kgN/ha/ann.

Table 3 above also gives the ranking of legumes and grass/legume mixtures in terms of the profitability per hectare. The main conclusions from the LEGSIL project in this regard are as follows:

1. Red clover and grass-red clover mixtures were consistently among the most profitable legumes to grow as silage.
2. With the exception of Germany, white clover, especially as part of a grass-clover ley, appears to be an attractive forage crop.
3. Lotus and galega, whether as pure crops or mixtures, are generally projected to be less profitable than red clover, white clover and lucerne.
4. Except in the UK, forage legumes generally appear to perform better as part of a grass-legume mixture than as sole crops.

The LEGSIL researchers also calculated the benefits of organic dairy systems relative to conventional fertilised grass systems. Taking account of the organic milk price and feed costs at the time (year 2000), organic systems based on red clover and white clover, whether grown as sole crops or in mixtures with grass, showed improvements in profits in excess of 75 per cent.

Disease and pest issues relating to choice of legume species
After a period of approximately 30 years during which red clover was relatively unpopular, there is again considerable interest in the crop, probably as a result of the expansion of organic farming in recent years and observation by non-organic farmers (and seed merchants) of the benefits obtained from red clover by organic farmers. However, it is important to bear in mind that red clover is susceptible to pathogens and parasites which can be persistent in the soil e.g. stem eelworm (*Ditylenchus dipsaci*) and *Sclerotinia trifoliorum.* It is also reported that white clover fatigue, associated with clover cyst nematode, is an increasing problem in Denmark (Soegaard, 2006). Thus, although the agronomic attractions of these two species are quite clear, it also seems prudent, to reduce the possibility of persistent disease and pest problems building up in any given field, that each of the two species should not be sown on a continuous basis, but ideally should be alternated with other legumes. Kadziulis (2001) found that, in Lithuania where red clover is the main perennial legume grown for cutting, the long term adverse effects of frequently growing red clover lasted for 7-9 years,

and concluded that yield was maintained better where red clover was alternated with either lucerne or white clover with a 3-4 year gap between red clover crops. In the Danish situation, Soegaard and Moller (2006) have identified that birdsfoot trefoil, black medick and crimson clover suffered significantly lower levels of attack by clover cyst nematode in known infected fields, compared with white clover, red clover and lucerne, and suggest that legume species diversification in the rotation may be a solution to clover fatigue.

The alternative approach to such problems is to use varieties which are known to have a good level of resistance to these diseases and pests. The other problem with these species which requires a plant breeding approach is the high level of oestrogens in the herbage which can reduce fertility in ewes. Unfortunately, the amount of breeding effort in the UK on red clover has been minimal over the last 30 years because of the lack of popularity of these species. Thus there are relatively few varieties of these species which have undergone National List testing in the UK. This situation is changing, but plant breeding is a slow process. One way to short circuit this issue would be to screen varieties, of red clover for example, bred in other countries, to test their suitability for UK conditions.

As a result, the number of varieties of red clover and lucerne for which disease resistance (and oestrogen) scores are available in the NIAB Herbage Varieties Guide is very small. There is a need for all varieties of white clover, red clover and lucerne to be screened for resistance to these diseases and pests. The need for this data will also grow as more conventional farmers begin to move to legume based grassland systems.

2.2 Grass & clover variety selection

Official testing of grass and clover varieties is undertaken in field trials in England, Scotland and Northern Ireland at two levels:

a) New varieties are tested at a range of sites throughout the UK to determine that they have value for cultivation and use (VCU) before they can be included in the UK National List. This testing programme covers the following species: in the grasses, perennial ryegrass, Italian ryegrass, hybrid ryegrass, timothy, and in the legumes, white clover and red clover. In these National List trials, varieties are tested in two trials sown in consecutive years, with each trial being monitored over a period of three growing seasons (two for IRG and red clover). NL trials are funded jointly by the breeders themselves and by Agriculture Departments in the devolved administrations. Grass and clover variety testing is undertaken in England by NIAB, in Scotland by SAC and in Northern Ireland by the AgriFood and Biosciences Institute (AFBI).
b) Recommended List trials extend the evaluation of the varieties in further additional trials, again for a three-year monitoring period, thus giving useful additional data on yield and persistence. These trials are funded ultimately by producers themselves, via a levy imposed on seed sales by participating seed merchants (England, Wales and Scotland only). From the producers' perspective, it is important to ensure that their seed merchant is a participant in the levy schemes, since it is only by doing this that the merchant has access to detailed performance and persistence data on individual varieties.

The data provided for grass varieties in the NIAB Herbage Varieties Guide includes information on overall yield and digestibility, annual yields and seasonal growth patterns under grazing and conservation managements, ground cover, winter hardiness, disease resistance, etc. For white clover varieties, the Guide includes data on annual yield of clover, yield of grass + clover, seasonal ground cover under hard defoliation, slug damage, etc. There is clearly a need, as indicated above, for both more breeding effort and more testing, and comprehensive observation, on red clover and lucerne, for which the choice of varieties on the UK National List is fairly limited. Another issue in the selection of varieties is the requirement in the standards to use seed which has been produced organically. It is an issue for debate whether UK organic farmers should be forced to use varieties which have not been tested in UK National List or Recommended List trials, simply because they are the only varieties available as organic seed, although, as highlighted below, the NL and RL testing protocols may not in any case be the most relevant for organic conditions.

These variety testing programmes are undertaken under non-organic, fertilised conditions, and it is possible that under organic conditions where soluble fertilisers are not used, the variety rankings may not be the same. This question applies to the relative rankings of both clover and companion grass varieties and is an issue for conventional agriculture also, since the average use of N fertiliser on grassland in the UK has fallen over the last 8-10 years from circa 120kgN/ha/ann to circa 75kgN/ha/ann. In the final report of Defra project VS 0129, the contractor IGER indicated that research was needed to determine if changes were required to VCU trials protocols to take account of this reduced use of N and increased conversion to organic (Anon, 2003).

IGER reported that in three separate trials of the same nine white clover varieties, each at a different level of fertiliser N application, two clover varieties gave consistently better yields at the lower N treatments, relative to the other varieties (Williams et al, 2001).

The issue also includes the relative competitiveness of grass varieties with white clover in low N situations. Modern white clover varieties have been bred to yield and persist in competition with perennial ryegrass because they are evaluated under conditions of fairly high levels of fertiliser N. In organic farm practice, however, where no mineral N is applied, it is possible that the perennial ryegrass varieties currently being used do not have the competitive ability to compete with clover in these conditions. It was suggested that this may be one of the reasons for the increasing number of reports of white clover becoming too dominant.

Nilsdotter-Linde and Bergkvist (2005) addressed this issue in a series of trials at two sites in Sweden, comparing a range of varieties of perennial ryegrass and Festulolium (a cross between perennial ryegrass and meadow fescue) and of grass variety mixtures of the two grasses, in combination with white clover. They concluded that clover content in short-term leys could be restricted by using competitive and persistent varieties of grass, but it could not be shown that grass mixtures were any more competitive than their constituent components.

As part of Defra Project VS 0129, IGER also reported the results of a survey of 275 farmers (including 109 organic farmers) regarding their view on the three most important traits for seed mixtures. For organic farmers these three were: persistency (22% of producers) (31% if ground cover included), total annual yield (22%) and early spring growth (13%). At the time, early spring growth was not weighted in decisions on VCU rankings of grasses, and early spring growth was given a low weighting in clover rankings. This survey also revealed that 74% of all farmers indicated that they were keen to use red clover.

In a subsequent Defra funded project VS 0133, the contractor NIAB assessed a range of perennial ryegrass varieties and white clover varieties under normal N, low N application under organic management conditions, specifically to assess whether the rankings were the same under the different management systems (Anon, 2006a). The conclusions from this project need to be treated with caution since there was only one sowing year and two trial sites (and the loss of one site in one year for the organic comparison). However, for **perennial ryegrass varieties**, the results indicated that the ranking between varieties was similar under normal N and low N application systems (where the grass was sown as pure stands), but was completely inverted under organic management (where clover was included to supply the N). It is possible that, in the organic system, total DM yield may have been higher with the less competitive varieties of ryegrass due to the additional growth of clover. Thus, although because of the limited dataset it is not possible to conclude statistically that the conventional variety testing system does not apply to varieties under organic management, the data does suggest that this is at least a possibility. In contrast, a series of trials in Switzerland comparing Italian ryegrass varieties at three sites including an organic site, with similar objectives to Defra Project VS 0133, but in which all varieties were sown as pure stands (i.e. without a clover companion), the ranking of the varieties at the organic site was the same as at the conventional sites (Suter et al, 2005). Given that a clover companion is essential in an organic system, the relevance of this result is questionable.

In the study of **white clover varieties** in the Defra Project VS 0133, the limited dataset suggests as for perennial ryegrass, that the variety ranking is different between the normal management protocol and the organic management system. The conclusion of the contractor was that the non-organic management (200kgN/ha/ann) favours large leaved varieties such as Alice which are better able to compete and co-exist at this level of N input, but which under organic management may be too competitive and come to dominate the sward. They suggest that in order to achieve a better balance between clover and grass under organic management, small- and medium-leaved varieties of white clover should be used.

The complex inter-relationships between varieties of grass and clover in a mixed sward is difficult to disentangle, given these potential varietal differences in competitiveness in both species. In addition, it is necessary to consider also the change in competitive balance over time. It is clear that in a mixed sward, where the ley follows an arable cropping phase and soil N status is low, clover tends to dominate in the early stages of the life of a ley. As the clover fixes N and builds up soil N content, the grass companion is favoured and clover content declines (Schwinning and Parsons, 1996). This may happen regardless of the competitive abilities of the ryegrass and clover companions. Thus, in addition to the need for variety testing to be undertaken under organic (or at least zero N application) conditions, this also highlights the need, in planning grass/clover variety trials, a) to take account of the soil N status and b) ideally to undertake the trials over a sufficiently long period of time.

2.3 Grass-clover mixtures

Historically, much more research is undertaken on individual species and varieties than on grass-clover mixtures. In the early years of grassland science, mixtures contained a very wide range of species, but as grassland management became more intensive and as scientific knowledge of the characteristics and performance of species and varieties expanded, mixtures were simplified. The principle behind sowing a mixture rather than a single species or even a single variety is that a mixture is likely to exploit the environment more efficiently and be less sensitive to environmental and disease or pest perturbations. Clearly this is logical and fits well with organic philosophy. However, the design of the mixture should still be based on sound knowledge of species and variety characteristics, rather than a blunderbuss approach of including a large range of species, in the hope that at least some of them will establish and flourish in the conditions. It is logical, for example, to utilise species that are recognised as having significant agricultural value and which have been the focus of breeding programmes, rather than using secondary species, except for very specific purposes. It is also important to remember that, although the composition of the seed mixture is important, the management system employed, including the establishment procedure, has an over-riding effect on botanical composition (e.g. Jones (1939), Jones (1933)).

One of the very few recent projects to examine multi-species seed mixtures is Defra project OF 0317, undertaken at the Ty Gwyn dairy unit at Trawsgoed by IGER as contractors (the development of organic milk production systems) (Anon, 2006b). This was a systems project comparing two dairy systems; SS, a self sustaining system which in which all feeds were produced on the unit itself, and PC, in which all concentrate feeds were purchased. There was a progressive change in forage policy of the PC system which moved from a rotational system with single or two species leys to a multi-species ley intended for a 10 year duration. This multi-species ley included the following species: hybrid ryegrass, perennial ryegrass, timothy, cocksfoot, meadow fescue, creeping red fescue, smooth-stalked meadow grass, crested dogstail, red clover, white clover, alsike clover, birdsfoot trefoil, chicory, ribgrass, salad burnett and yarrow.

At the time of the final project report, the multi-species leys were only between two and four years old. Observations in these first years showed a benefit to the multi-species ley. There was non-uniform establishment of species; timothy and meadow fescue were dominant in wetter areas, cocksfoot in drier soils within same field. Red clover was dominant in the first two years, succeeded by white clover as the main legume species from year three onwards. During the observation period, mean yield of the multi-species ley was 7.99tDM/ha compared with 5.85 and 5.82 tDM/ha from permanent pasture and re-seeded leys.

Whilst these are positive results, it would be necessary to observe these leys over a full ten year period to draw comprehensive and reliable conclusions about such a policy. For example, it could be expected that, compared to a rotational, short-term ley system, problems with perennial weeds such as docks will increase with time on swards that are cut annually, as many swards are in a dairy system. It is likely also that over time the botanical composition will reflect the management imposed, e.g. swards which are cut annually will develop into swards dominated by timothy and ryegrass. It should also be noted that the re-seeded leys in the yield comparison above were ryegrass-white clover swards, whereas, as indicated, the multi-species leys were dominated by red clover, a higher yielding species, during this early observation phase. Thus it cannot be concluded yet from this work that the policy of a long-term, multi-species ley is necessarily better in terms of reducing financial and energy inputs, controlling weeds, and maintaining an adequate supply of high quality forage compared with a policy of rotational shorter-term swards sown for specific purposes in specific fields.

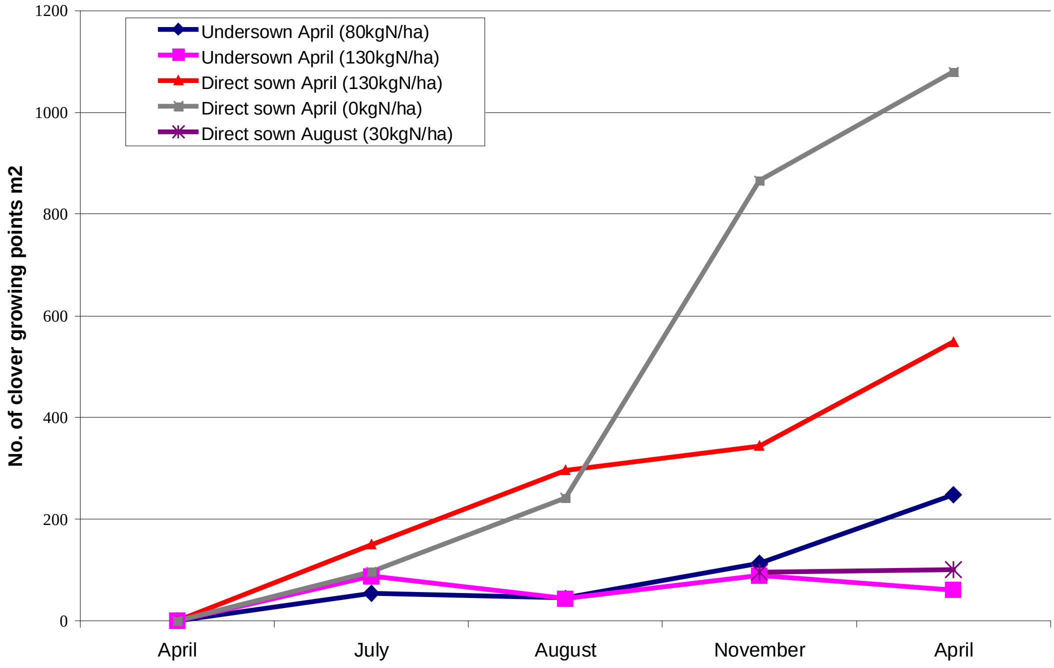
Decisions on the composition of seed mixtures should be based on a) soil and climatic conditions at the site b) the intended duration of the ley, and c) the intended use of the ley (cutting or grazing, etc). The potential roles in seed mixtures of the main grass and legume species has been outlined in Section 2.1 above and in Appenices 1 and 2. As indicated at the start of this section, very little research has been undertaken on mixtures, although there has been a little work undertaken in Europe (Haas, 2003; Iepema et al, 2006; Rauber and Hof, 2003; Suter, 2005). Much of the European work has focused on red clover and other forages primarily grown for silage. Both Loges (1998) and Leisen (2003) highlight the fact that red clover in mixture with perennial ryegrass results in a higher protein herbage compared to a red clover-Italian ryegrass mixture. This may be important in a dairy system for example where the aim is to maximise the protein content of the silage. Both authors also report that red clover-perennial ryegrass mixtures result in a higher N fixation and a higher uptake of N in the following crop. Leisen (2005) reports in a separate paper that when, in Germany, grass-clover mixtures were undersown in a cereal (i.e. sown in spring), red clover often dominated. Where the mixture was sown after the cereal harvest, perennial and Italian ryegrass dominated, whilst white clover and meadow fescue did not show good establishment. These results reflect experience in the UK also and reflect the influence of sowing date rather than issues about the mixture per se.

2.4 Management issues

Establishment

Compared with conventional producers, organic farmers in general seem to have little problem establishing a satisfactory clover content in their leys, probably because they do not use mineral nitrogen fertiliser and herbicide. The effect of undersowing, nitrogen fertiliser and sowing season on white clover establishment in a conventional situation was studied by Younie (1998) (Fig 1).

Figure 1. Effect of sowing treatments on white clover establishment.

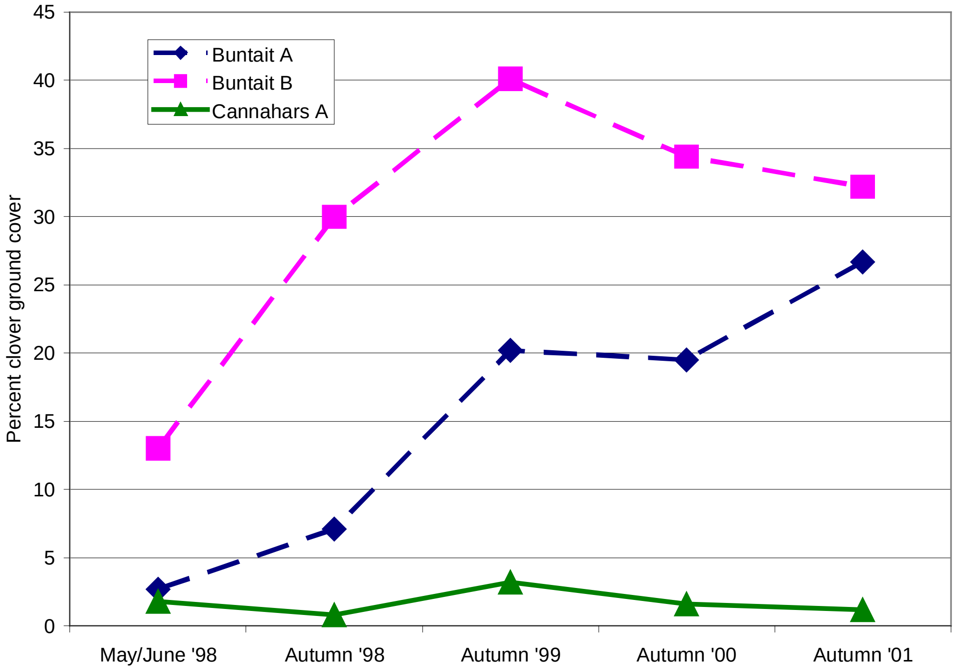


(Source: Younie, 1998)

The data shows the very positive effects of not using a cover crop, avoiding the use of N fertiliser and sowing in spring rather than late summer (at least in the north of Scotland). The adverse effect of undersowing will be less in an organic situation because organic cereal crops will be less competitive, and most organic farmers achieve satisfactory clover content by undersowing. In fact competition from undersown red clover can be a problem in organic spring cereals, although this is often the result of a less than vigorous barley (rather than oats) crop, when farmers fail to provide sufficient FYM, or the result of a wet growing season, which favours the undersown grass-clover rather than the cereal (Younie, 1998).

Oversowing clover into existing swards has become a common, cost-effective, tool for increasing clover content. The EFFECT project was an EU-funded project to examine the potential of oversowing white clover. The critical factors for success in oversowing are selection of relatively open swards, soil moisture content, and control of the existing vegetation. In the dry east of the UK, oversowing should probably always be done in early spring when there is sufficient soil moisture. The effect of density of the existing sward is shown in Figure 2 below. Oversowing was not a success in field Cannahars A which was a very dense meadow grass-Agrostis sward, whereas it was successful in the two Buntait fields which were primarily composed of perennial ryegrass (Younie, 2002).

Figure 2. Effect of oversowing on clover ground cover on three organic grass swards



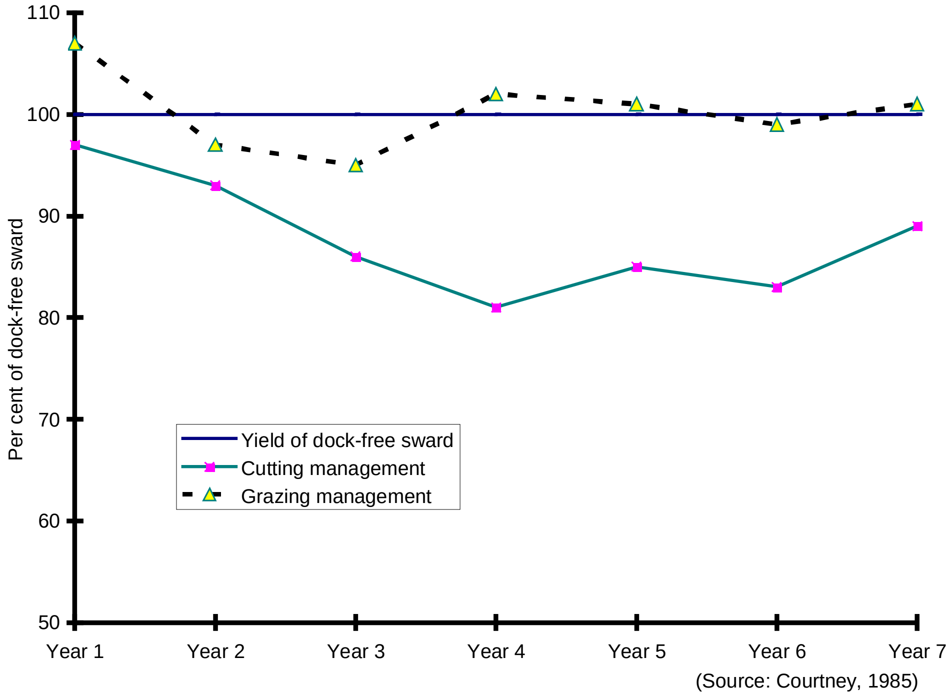
(Source: Younie, 2002)

Oversowing red clover into existing red clover, in order to extend the life of the sward, is also a possibility and of course 2nd year red clover swards will tend to be fairly open, albeit rather competitive (Nykanen et al, 2002).

Weed control
Control of perennial weeds, particularly docks, is one of the greatest technical challenges in organic farming. A survey of 156 organic farmers in Germany showed that 80% of farms had problems with dock (Bohm and Finze (2003). On average each farm had dock on a fifth of its grassland. Direct control measures against the weed were rarely undertaken for labour and cost reasons. Despite much research no easy solution to control of docks has been found (Zaller, 2004).

Hopkins(1999) and Hopkins and Johnson (2002) reporting on Defra Project OFT 0115T) reported that soil aeration limited the expansion in dock numbers in the sward, and that lower cutting height favoured the dock but that frequent cutting (4-5 week intervals) resulted in lower dock populations than infrequent cutting (6-8 week intervals). This echoes the results of Courtney (1985) who found that Rumex abundance was reduced by 60% after six years of cutting 5 – 7 times per year. However, Zaller (2004) suggested that to control Rumex completely by cutting management would require cutting every two weeks. However it is clear that docks are less of a problem where the sward is grazed rather than cut (see Figure 3 below), and anecdotal observation confirms that docks become more of a problem in long-term swards, cut annually for hay or silage. A strategy for minimising the threat from docks should therefore include the adoption of a rotational system of short-term leys, particularly for fields required for conservation, and if possible alternating grazing and cutting from year to year.

Figure 3. Influence of cutting or grazing management on effect of docks on yield

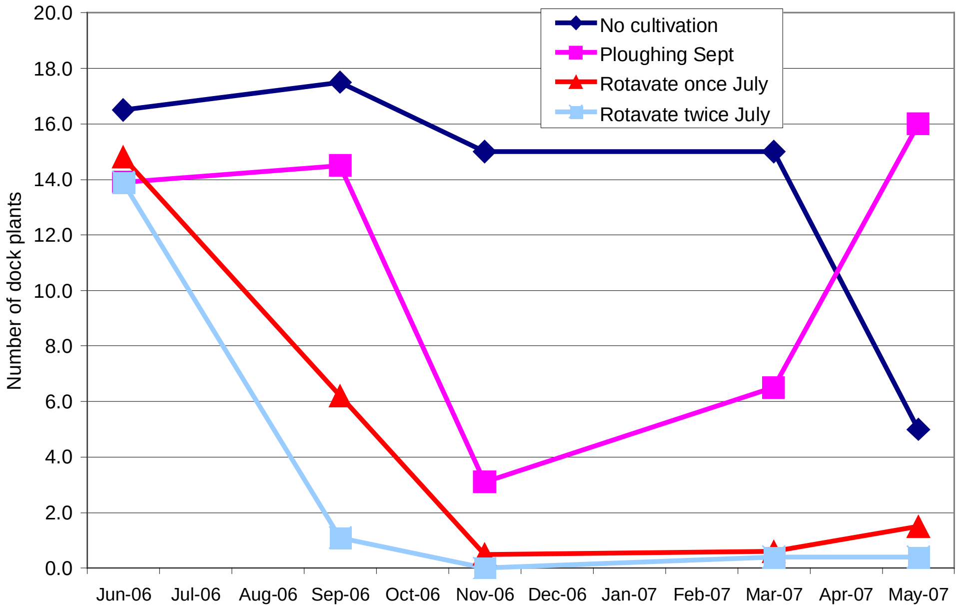


Where dock infestations become so severe that it is imperative that remedial action is taken, control can be achieved (at a cost), by surface rotavation in June followed by summer harrowing to desiccate the crowns, deep ploughing in September, followed by a winter cover crop of forage rye (Philipps, 2001; McRae, 2007) and a spring arable crop. Figure 4 illustrates the potential reduction in dock population which is possible with this technique.

A field-scale observation study was undertaken as part of Defra Project OF 0319 (Anon, 2005) in which dock cover in a plot grazed by pigs was reduced from 33% pre-treatment in 2002 to 0.6% in 2003, then increasing to 2% by 2004. On two plots which were repeatedly cultivated, cover fell from 27% to 1%, before increasing to 2% and 3% cover respectively. Observations indicated that the pigs did not consume many dock roots, but their rooting activity brought dock roots to the surface and moved them around continually.

The effectiveness of this type of cultural control, both the use of pigs and the rotavation and repeated harrowing technique, is likely to be dependent on reasonably dry weather.

Figure 4. Effect of four cultivation treatments on number of dock plants per 13.6m long plot diagonal transect.



(Source: McRae, 2007)

2.5 Systems

Defra have funded a number of organic systems-based research projects which closely relate to grass/clover leys.

Defra Project OF 0328, undertaken by ADAS as contractor, was a desk-based modelling study specifically aimed at optimising the production and utilisation of forage for organic livestock (Anon, 2004). The contractor concluded that the main problem on organic livestock farms is to ensure that a sufficient quantity of conserved winter forage of appropriate quality is produced without increasing pressure on grazing, and that this depended on the season and on the clover content of the sward. Specifically, the following solutions were highlighted:

- efficiency of forage utilisation is more important than the type of system
- Self-sufficient systems with no bought-in feed were more agronomically robust and sustainable than systems relying on purchased feed, but resulted in lower output per given land area and a severe economic disadvantage

More specifically, in terms of improving forage utilisation, the contractor suggested that farmers should avoid depending on a single large cut of forage (which would compromise quality) and adopt one or more of the following procedures:

- Graze the sward before shutting up for silage
- Make an earlier, smaller first cut of high quality forage and a larger, higher protein second cut
- Introduce a second high protein forage for silage, such as whole crop cereals with vetches, peas, lucerne or lupins, to reduce reliance on bought-in proteins
- Either layer different forages into a single silage clamp (or put different forages into different clamps), rather than a Dorset wedge system. The layered system means the composition of the forage will be reasonably consistent.
- A second forage in the system will make it more agronomically robust by introducing a crop rotation, that will also result in an increase in forage dry matter intake.
- Always analyse conserved forages so that a balanced winter ration can be made up.

This project was undertaken between 2002 and 2004 but the organic sector has changed since then, particularly in terms of the cost of feeds. The importance of maximising the efficiency of forage utilisation, highlighted by the contractors, must be even greater under current economic conditions. Essentially this approach is one which is aimed at reducing purchased inputs and becoming more self-sufficient. A fully self-sufficient system may still be at an economic disadvantage even today but it is likely that the optimum has probably moved more in the direction of self sufficiency. The modelling exercise needs to be re-run taking account of the recent substantial increases in the cost of organic feeds.

There is an issue in this report regarding the conclusions drawn by the contractor about the potential from 100% forage diets. The data presented in the report seems to suggest that 100% forage diets, based on high ME forage, will support relatively high levels of animal performance (see Table 4). However, ADAS concludes that diets based on 100% forage will only support relatively low levels of dairy production and LWG in beef production, which seems to conflict with the data in Table 6.

Table 4. The effect of forage ME and forage concentrate ratio on livestock production (Anon, 2004)

Production system	**Forage:conc ratio**	**Forage ME (MJ/Me/kg DM)**		
		12	**10**	**8**
For dairy production:				
Theoretical milk yield (litres) at varying levels of	100:0	27	20	13
forage energy level and using a concentrate of 13 MJ	80:20	28	22	17
ME/kg DM	60:40	29	24	20
For sheep production:				
Calculated energy intake (MJ/day) of ewes in late	100:0	18.0	15.0	12.0
pregnancy at varying levels of forage energy level and	80:20	18.3	15.9	13.5
using a concentrate of 13 MJ ME/kg DM	60:40	18.6	16.6	15.0
For beef production:				
Calculated liveweight gains (kg/day) of growing beef	100:0	1.0	0.7	0.4
cattle (350 kg) at varying levels of forage energy level				
and using a concentrate of 13 MJ ME/kg DM	60:40	1.2	0.9	0.7
Calculated liveweight gains (kg/day) of growing beef	100:0	1.2	0.9	0.6
cattle (500 kg) at varying levels of forage energy level				
and using a concentrate of 13 MJ ME/kg DM	60:40	1.4	1.1	0.9

The advantage of a livestock system based on purchased concentrates is that a higher stocking rate can be maintained. In effect the purchased feeds are buying in more hectares. This effect is seen also in another Defra project (OF 0317) (Anon, 2006b), which compared organic milk production systems based on self sufficiency in all feeds including cereal (SS) with a system based on purchased concentrates (PC). The SS system had a stocking rate of 1.08 to 1.28 cows per ha with circa 17% of land area used for cereals. The quantity of concentrates available for feeding ranged from 0.33t to 0.67t/cow, and milk yields of 4817 to 6695 litres per ha with between 73 and 86.0% of annual milk output produced from forage. The PC system supported between 1.54 to 1.96 cows/ha with 8743 to 12532 litres milk produced per ha. The level of concentrate feeding varied between 1.34 t/cow to 1.74 t/cow, leading to between 35% and 53% of total annual milk being produced from forage.

The Holstein Friesian cows in this project (at Ty Gwyn, Trawsgoed) were well suited to the PC system where concentrate input was over 1.0 t/cow, but in the SS system, there was insufficient energy in the diet in early lactation, leading to problems of reduced milk persistency, lower milk proteins, and fertility problems. Thus a different type of cow might be required for this type of SS system. While the SS system achieved a high level of self-sufficiency, it required a more complex crop rotation and was less flexible in meeting the total annual feed requirements of the cows. The PC system is less sustainable, more vulnerable to market trends in supply and price of purchased feeds, but has the potential to produce a higher output of milk per ha and improved energy supply to the cows in early lactation.

The recent shortage and increase in the price of organic feeds has highlighted the conclusion, in both projects OF 0328 and OF 0317, about the sustainability of systems based on purchased feeds. The comparison needs to be re-modelled. As indicated above, the economic optimum has probably moved more in the direction of self sufficiency compared to when these projects were undertaken, and certainly the importance of efficient forage production and utilisation has never been greater.

2.6 Fertility building effects

Defra project OF 0316 (Anon, 2006c) focused on providing improved guidance on the use of fertility building crops in organic farming. In addition to a literature review, field experimentation, at two sites, compared red clover and ryegrass, either cut and mulched or cut and removed, with or without FYM. Cutting and mulching, and addition of FYM, reduced N fixation but gave higher levels of offtake in the subsequent perennial ryegrass indicator crop. Similar effects were also observed in Germany by Loges et al (2000) who compared white clover, red clover and lucerne (in mixture with grass), either cut and mulched or herbage removed. N fixation was highest in red clover and lucerne, and was highest when herbage is removed (320-340 kgN/ha in red clover and lucerne respectively, cut and removed), confirming results from Defra Project OF0316, but N in plant residues was higher when the crop is cut and mulched. Mulched legume swards in the trial of Loges et al (2000) left at least 200 kg N/ha as mulch, stubble and roots, whereas most cut swards left not more than 115 kg N/ha as plant residues after the last cut. As indicated in Section 2.3 above, red clover-perennial ryegrass mixtures result in higher N fixation than red clover-Italian ryegrass mixtures, because of the higher proportion of clover in the crop (Loges,1998 and Leisen,2003).

The recommendation from Defra project OF 0316 was to cut and remove herbage during the fertility building phase in order to maximise N fixation. In addition, in this project, a number of other novel legumes (17 legumes plus perennial ryegrass) were studied at two sites. The conclusion was that sweet white clover, large birds-foot trefoil and subterranean clover fixed as much N as white and red clover at one of the sites (ADAS High Mowthorpe), but at the second site, which had a high N status soil (Duchy College) none of the legumes outperformed the ryegrass.

3. Conclusions

Analysis and detailed discussion of the research results have been embedded in Section 2 at the relevant place.

The **key messages** from this review are as follows:

Grass species
The ryegrasses are the most useful group of grass species for organic ley farming in UK, because of their desirable agronomic characteristics and the wide range of varieties available. Nevertheless, species such as timothy and cocksfoot are also useful species and should be included in mixtures in specific circumstances.

Legume species
White clover is the most flexible herbage legume species given its adaptability for both grazing and cutting management. For specific cutting swards, red clover combines both high yield and adaptation to a wide range of soil types. Lucerne is also very productive as a silage or hay crop but has more restrictive demands in terms of soil type.

Grass and clover varieties
There is a large number of varieties available of perennial and other ryegrasses which allows varieties to be selected for a range of purposes: cutting or grazing, short or long duration leys. A reasonable range of white clover varieties also exists, suitable for different management purposes. The NIAB Herbage Varieties Guide provides comprehensive information for these main herbage species. However, recent breeding effort in red clover has been limited and improvements need to be made in its persistence, oestrogen content, and resistance to pests such as stem eelworm. Continuous use of red clover in the same field, for example, could cause serious persistent eelworm problems. There is a need for more breeding and more comprehensive screening of red clover and lucerne varieties, in order to provide better information for producers.

There is an unresolved issue about the relevance of NL and RL variety testing protocols for organic situations. The limited Defra research undertaken thus far does suggest that variety rankings obtained under non-organic conditions do not necessarily apply in organic conditions where no fertiliser N is applied. This revolves around the relative competitiveness of the varieties (both grass and clover) under different levels of soil N status.

Also unresolved is the issue of whether simple or complex herbage seed mixtures are most appropriate for organic farming. This is unresolved primarily because of lack of research. Early conclusions from Defra project OF 0317 suggest that yield in the early years may be higher with the multi-species mixture but this can be explained by the presence of red clover in this mixture, which was compared with a grass-white clover 'control' mixture. This reviewer concludes, therefore, that the composition of seed mixtures should be specific and based on a) the soil and climatic conditions at the site b) the intended duration of the ley, and c) the intended use of the ley (cutting or grazing, herbal, etc).

Management: establishment

Research and farm experience highlight the improved establishment of clover which is obtained by sowing in spring, without a cover crop, compared with sowing in late summer. This is true both for sowing in a prepared seedbed and also in an oversowing situation.

Management: Weed control

Despite considerable research effort, no simple and inexpensive method of dock control has been found. Minimising the risk of occurrence of a dock problem is likely to involve a number of approaches including rotational and grassland management techniques. Severe infestations can be effectively dealt with, at a cost, by the rotation/harrowing/desiccation technique.

Systems

Defra project OF 0328 highlighted the importance of efficient forage use, and this has come into even sharper focus with the subsequent substantial increase in organic feed costs. Multi-cut silage system is advised, aimed at achieving high quality forage to minimum purchased feeds. Both this project and Defra project OF 0316 concluded that a forage system based on purchased concentrates, while being less agronomically robust and sustainable than a system which was totally self-sufficient in feed, was substantially more profitable. Given the increase in feed prices, this comparison needs to be re-modelled for a range of product prices and input costs.

Fertility building effects

When legumes are grown specifically as green manures, the highest quantity of N fixation is obtained from red clover (and lucerne on the appropriate soil type). N fixation is higher when it is grown with perennial ryegrass than with Italian ryegrass and when the crop is cut and removed rather than cut and mulched.

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Appendix 1. Characteristics of main grass species used in UK agriculture

Perennial ryegrass (*Lolium perenne*)

Attributes	Shortcomings
Easy to establish Productive in fertile soils Digestible Palatable Easy to ensile (high sugar content) Wide range of varieties available, suitable for wide range of management circumstances (cutting, grazing, short-term and long-term swards)	Less productive in dry, infertile soils Some varieties susceptible to winter kill Lower mineral content compared with legumes and forage herbs

Italian ryegrass (*Lolium multiflorum*)

Attributes	Shortcomings
Easy to establish Very productive in fertile soils Early spring growth Digestible Palatable Easy to ensile (high sugar content)	Not persistent (assume two years) Susceptible to winter kill

Hybrid ryegrass (*Lolium hybridum*)

Attributes	Shortcomings
Higher yielding than perennial but lower yielding than Italian ryegrass Other attributes also intermediate between the two parent species	More persistent than Italian, but less persistent than perennial ryegrass (assume three years)

Timothy (*Phleum pratense*)

Attributes	Shortcomings
Palatable Suited to heavy, wet soils Well suited to cutting management Early spring growth Very winter hardy	Slow to establish Less productive than perennial ryegrass Lower sugar content than ryegrasses – less easy to ensile

Cocksfoot (*Dactylis glomerata*)

Attributes	Shortcomings
Drought resistant, well suited to dry sandy soils Early spring growth Winter hardy	Slow to establish Less productive than perennial ryegrass Less digestible than perennial ryegrass Unpalatable if allowed to mature Lower sugar content than ryegrasses – less easy to ensile

Meadow fescue (*Festuca pratense*)

Attributes	Shortcomings
Tolerates wide range of climatic conditions Tolerates wide range of soil moisture conditions	Less suited to cool, high rainfall situations

Red fescue (*Festuca rubra*)

Attributes	Shortcomings
Suited to poor soil fertility Good tolerance of drought	Very fine rolled leaves reduce its palatability to stock

Smooth-stalked meadow grass (*Poa pratensis*)

Attributes	Shortcomings
Suited to poor soil fertility Good tolerance of drought Tolerant of grazing and heavy trampling	Slow to establish

Tall fescue (*Festuca arundinacae*)

Attributes	Shortcomings
Very tolerant of drought Tolerates wide range of climatic conditions Used mostly for production of dried grass	Coarse leaf surfaces – unpalatable to stock

Appendix 2: Characteristics of main herbage legume species used in UK agriculture

White clover (*Trifolium repens*)

Attributes	Shortcomings
Productive N-fixing species High voluntary intake characteristics and nutritive value (protein- and mineral-rich) Adapted to a wide range of soil conditions Well adapted to both cutting and grazing management Stoloniferous growth habit so very persistent	Susceptible to diseases and pests. Can cause bloat

Red clover (*Trifolium pratense*)

Attributes	Shortcomings
Highly productive, N-fixing species High voluntary intake characteristics and nutritive value (protein- and mineral-rich) Adapted to a wide range of soil conditions. Erect growth habit – well adapted to silage management Good winter hardiness.	Relatively short-lived species Assume 2-3 harvest years - yields decline with age Unsuited to intensive grazing Monocultures prone to weed invasion Susceptible to diseases and pests, e.g. stem eelworm Can cause bloat Can reduce fertility in breeding ewes if grazed during immediate pre-mating and mating periods.

Alsike clover (*Trifolium hybridum*)

Attributes	Shortcomings
Tolerates cold, infertile, acidic soils Erect growth habit – well adapted to cutting management	Relatively short-lived, (assume 2-3 years) Yield declines with age. Lower yielding than red clover on fertile soils Can cause bloat

Lucerne (*Medicago sativa*)

Attributes	Shortcomings
Highly productive, N-fixing species High voluntary intake characteristics and nutritive value (protein- and mineral-rich) Requires relatively high soil pH and well drained soils. Erect growth habit – well adapted to silage management Drought resistant	Unsuited to intensive grazing Lacks long-term persistence (assume 4-5 harvest years) Susceptible to many diseases and pests Can cause bloat Can reduce fertility in breeding ewes

Sainfoin (*Onobrychis vicifolia*)

Attributes	Shortcomings
Productive, N-fixing species High voluntary intake characteristics and nutritive value (protein- and mineral-rich) Erect growth habit – well adapted to hay or silage management	Slow to establish Unsuited to intensive grazing Requires high soil pH Tannin content reduces risk of bloat