Advisory Leaflet

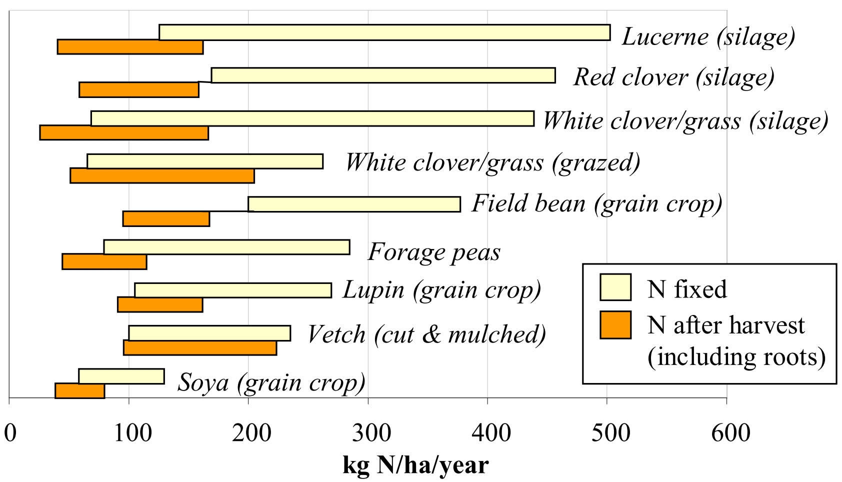
Soil Fertility Building Crops in Organic Farming

Organic farming aims to be self-sufficient in nitrogen (N) through fixation of atmospheric N_2 by legumes, recycling of crop residues and application of manures or composts. Nitrogen in legumes comes from **uptake of soil N** and from **fixation of N from the atmosphere**. Only the fixed N represents a true import of N on to the farm. As well as legume based leys, organic rotations also often provide a supplementary boost of N during the fertility depleting phase by the growing of a leguminous crop, such as field beans or peas. Despite reliance on legumes for N, much remains to be understood about how to maximise N fixation and make most efficient use of the fixed N. This leaflet summarises information taken from a comprehensive review of the literature as part of a current DEFRA-funded study to optimise the use of fertility building crops in organic farming.

How much N is fixed under UK conditions?

The amount of N fixed by different legumes is determined by the inherent capacity of the crop/rhizobium symbiosis to fix N, modified by the crop's growing conditions (e.g. soil, climate, disease), crop management and length of time for which the crop is grown. Consequently, the influence of all of these factors means that a wide range of values

Provisional ranges for quantities of N fixed and remaining after harvest



have been reported by different researchers. However, for a particular legume species there is usually a close relationship between yield and the quantity of N fixed. The figure on previous page indicates the **range** of fixation estimates quoted for a number of leguminous crops.

Management to optimise N accumulation

The literature provides considerable evidence that management factors can influence N fixation by a legume. The presence of soil mineral N is generally thought to reduce fixation capacity (see box). Factors that will increase the soil mineral N pool include **manure application, cutting and mulching, grazing**. Fixation tends to decrease with **legume age**, mainly because the amount of soil N tends to increase. Consequently, there are many of these contradictions, which make management decisions difficult. For example, cutting and mulching is a standard practice in organic rotations, especially in stockless systems, yet it may be that such a practice is decreasing fixation and the amount of N imported into the rotation from the atmosphere. Also, harvesting of forage or grain will remove much of the fixed N and reduce the benefit to following crops (see figure). The benefit will be further reduced if straw and other crop residues are also removed from the field. However, much of the fixed N will be retained within the farm if the forage and grain is fed to stock on the farm rather than being sold. Other aspects of management affecting N-fixation include position of the crop in the cropping rotation, duration of cropping and methods of cultivation. These are detailed later. Growing the legume in a mixture with a non-fixing crop can increase the proportion of N obtained from the atmosphere. For example, in grass/clover leys, the grass utilises soil-N and thus avoids the build-up of N that otherwise might inhibit fixation. However, the presence of a companion crop also reduces the number of N-fixing plants per unit area.

Cutting	Grazing	Grain legumes
• Fixation is reduced for several days after cutting • If cut material is returned to the soil as a mulch this decreases fixation by increasing the soil N status • It is better to remove the material after cutting (e.g. as silage) but this has other management implications, especially on stockless farms	• Much of the ingested N is returned as excreta (as much as 90%) • Increases soil N pool and decreases fixation • There is a greater accumulation of N than under cutting	• Generally obtain a smaller proportion of their N by fixation • Harvesting of legume seed removes much of the fixed N from the field • Consequently, net effect on soil N status may be small • Greater benefit if seeds are fed on farm and N is returned as manure

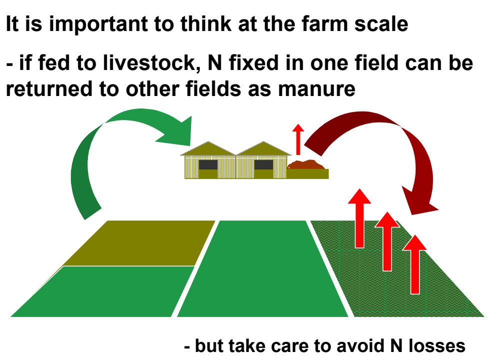
Thus, we know the factors that affect N build up. How are these translated into **practical advice? :-**

- In forage situations consider removal of cut material but don't cut too frequently
- Avoid returning cut and mulched material to legumes
- Accept that net input from grain legumes is lower and adjust rotation accordingly
- Don't apply high available N organic manures to legumes eg slurry and poultry manures

Rate of release of fixed N and minimising losses

Before the N from the legumes can be used by the next crop, it has to be 'mineralised' into plant available forms (nitrate and ammonium). Some will already be in this form, due to transformations during the life of the crop. Most, however, will need to be mineralised by microbial action after cultivation. Since mineralisation is a microbial process, the rate depends on environmental conditions (soil moisture, temperature, etc), soil texture (potentially slower in clays than sands) and also the composition of the crop material (fresh green residues decompose more rapidly than old 'stemmy' materials). The dynamics are therefore complex and we are using computer models to develop guidelines on the rates of breakdown.

Once mineralised, N is also susceptible to loss and it is important that as much as possible is retained for use by the crop. Losses occur mainly through nitrate leaching and, sometimes, ammonia volatilisation. Nitrate leaching can be minimised by ploughing the ley as late as possible in the autumn or preferably in the spring. However, this advice does not always fit with more practical considerations of preparing the soil for the next crop. Nitrate leaching after ploughing the ley probably represents the greatest N loss from the rotation. Ammonia volatilisation can occur from the cut foliage, but amounts are thought to be small. The main loss of ammonia is from manure (during grazing or after application). Whereas grazing losses are difficult to control, rapid incorporation of manure after application will reduce volatilisation losses.



Other Considerations

Management of cover crops - options/timing

- To reduce N leaching risk cover crops need to be established early in the autumn to ensure good crop growth and hence N uptake. Establishment techniques need to ensure conservation of soil moisture and ensure a good seed/soil contact.
- Covers should be chosen with due regard for the cash crops in the rotation so as to minimise the risk of pest/disease build-up. For example stubble turnips are not suitable for use in brassica rotations.
- Some covers are difficult to destroy in the spring and thus interfere with establishment of the cash crop.
- Some covers do not release N quickly enough to be utilised by the following crop. If the N is released too slowly and not fully used by the cash crop it is at risk of being leached in the following season. Mustard releases N very quickly, phacelia may be slow to release N.
- In livestock systems covers may be useful 'catch crops' to provide forage: for example sheep grazing

Crop sequences

- Various aspects of soil management can influence N-fixation. In many cases this will be through their effect on the soil mineral-N levels experienced by the legume, with the legume obtaining a greater proportion of its N from the atmosphere in low-N soils. Thus, as in most organic rotations, more N is likely to be fixed where legumes follow crops that have previously depleted soil-N levels.
- There will be differences in N-availability in different soils; for example, between soils on stockless farms and on predominantly livestock farms which are able to include a greater proportion of leys in the rotation or between soils of contrasting textures. However, it is possible that soil-N status has less effect on fixation in mixed swards than where the legume is grown alone. In high-N soils, N uptake by the non-legume component of mixtures may reduce mineral-N concentrations sufficiently to avoid the inhibitory effects on fixation.
- The optimum build up period for white clover swards is about three years.
- Some legumes are less suitable as annual build-up crops due to slow establishment and growth.

Bi-cropping

- The use of permanent beds of a legume grown alongside a cash crop has potential as an alternative technique in organic farming. Such systems may allow both cash crops and fertility-building crops to be grown every year. Companion crops also have the potential to reduce the impact of pests and weeds. The big disadvantage of companion crops is competition with crop plants for space, light, water and nutrients. The companion crop, therefore, is likely to have to be mown or grazed to control competition and encourage nutrient transfer. In a recent DEFRA project (OF0182) growing vegetables in single rows alternating with semi-permanent white clover strips mown frequently, competition was severe leading to failure of some crops and uneconomic yields of others. A much less intimate mixing (in space and / or time) of companion and cash crops is likely to be required for commercial success. However, such a system is likely to be of less benefit for weed, pest and disease control.

Costs

- The economic viability of conventional rotations in organic farming tend to be reduced by the need to have crops within the rotation purely for fertility building and not for their cash value, particularly where there are no livestock to utilise grass/clover and forage legume crops. The use of marketable grain legumes in stockless rotations enables some income to be derived from the fertility builder. The potential income is dependent on the market end point

Interactions with cultivations/seed bed preparation

- Cultivation practices that increase mineralisation of soil organic matter will lead to increased levels of soil-N with the result that following legume crops obtain less of their N from the atmosphere. A number of studies have demonstrated greater fixation in minimum tillage systems.
- Weed control requirements for bare ground and stale seedbeds increase the risk of soil N loss through leaching.
- Repeated cultivations for weed control increase mineralisation of N which increases the potential for N leaching losses.
- Fertility builders which are not easily destroyed by cultivation and seedbed preparation may become weeds in the following cash crop.

Interactions with pest and disease

Fertility building crops are subject to pest and diseases that can reduce their effectiveness at increasing soil N supply, there is also a risk of carryover into the following cash crop.

- Consider cropping history and previous pest and disease problems before selecting fertility building crops.
- Pest and disease risk is increased by selecting fertility building crops of the same 'type' as arable or vegetable cash crops. i.e. cruciferous legumes in rotations with brassica cropping.
- Maintaining a green cover in the autumn (either through early drilling or use of cover crops) to minimise leaching losses increases the risk of some pests and diseases – the 'green bridge' effect.
- Good soil management and drainage are important factors in reducing threat from soil-borne diseases and cultivation techniques can minimise the impact of some soil pests such a slugs.
- Bi-cropping can reduce pest and disease severity.

Interactions with other nutrients

- Where growth of legumes is affected by nutrient deficiency (or acidity) the potential for soil N build up is reduced. Phosphorus and some trace elements (e.g. molybdenum) are particularly important.
- The risk of sulphur deficiency is now widespread in the UK due to reduced pollution from industry.
- Clover competes poorly with grass for soil nutrients and therefore needs a plentiful supply of soil nutrients when grown in a mixture.
- High soil N reduces the fixation capacity of legumes.
- There is some evidence that mycorrhizal fungi are more common in organic farming systems and may increase the availability of other soil nutrients.

Organic manures

- It is necessary to supply adequate P and K to ensure satisfactory growth of legumes, particularly where there are large offtakes of soil nutrients, as in silage crops, root crops or intensive field scale vegetable production.
- On organic farms, these nutrients are most likely to be supplied as animal manures. As these materials also contain N, their use may inhibit N–fixation in the short-term and reduce clover contents in the longer term.
- These effects will be less with FYM and composts than with slurry and poultry manure which generally contains a higher proportion of readily-available N.

Other sources of information

- For more detailed information livestock farmers are recommended to obtain a copy of the Defra funded booklet: Managing Livestock Manures Booklet 4 - Managing manures on organic farms, or the computer package MANNER. These are available free of charge from ADAS Gleadthorpe Tel 01623 844331.

- Visit the project website for regular updates on progress and more detail on some of the issues covered in this leaflet:

  www.organicsoilfertility.co.uk

Organic Soil Fertility
Soil Nitrogen Management

Summary of Advantages/disadvantages of main legumes

Crop	Forage or cash crop potential	Vigour	Soil type	Climate	Seed rate kg/ha	Cost £/kg
Red clover	Large biomass for forage; high protein content forage; can cause bloat.	Deep rooting; vigorous growth; Can disappear in grazed swards; susceptible to stem nematode; typical productive life of 3 years; can be very competitive when undersown; erect growth habit.	Most soils, difficult on soil with high organic matter content.	Difficult to establish in autumn in the north.	10-15 + grass	6-7
White clover	Withstands heavy grazing; lower biomass productivity.	Viable for 5-9 years; good regeneration after drought; resistant to stem nematode; suitable for undersowing/ bi-cropping; prostrate growth has good ground cover; Slow establishment, best established in spring.	Most soils, difficult on soil with high organic matter content.	Dislikes waterlogged/ droughty conditions.	4 – 6 + grass	20-30
Crimson clover	Forage can be stemmy.	Resistant to clover rot; erect growth habit; unsuited to bi-cropping; autumn establishment difficult.	Tolerates a wide range of soil pH; dislikes heavy soils.	Dislikes waterlogged conditions.	15 + grass	6-7
Subterranean clover	Suitable for grazing and/or forage.	Can be undersown.	Neutral to acid soils.	Warm, moist winters and dry summers.	Not available	Not available
Lucerne/alfalfa	Fodder potential; has higher bloat risk as fresh forage.	Deep rooting; drought tolerant; Requires inoculum to establish; slow to establish; resistant to stem nematode; can be undersown; productive for up to 5 years.	Requires soil pH of 6+ in topsoil and subsoil.	Risk of winter loss/die back.	20 + inoculant	5
Vetch -	Highly productive biomass.	Late sowing possible; Very competitive; long flowering period. May be difficult to kill in spring; viable seeds can become weeds in subsequent crops.	Difficult to establish on heavy clay.	Dislikes waterlogged conditions.	60-120	1-1.50
Sainfoin	High protein forage; bloat free; high palatability.	Highly productive.	Intolerant of acid soils.	Not suited to autumn sowing; intolerant of waterlogging.	60-90	2
Birdsfoot trefoil	Low bloat risk; Lower biomass production.	Prostrate growth habit; can be undersown; tolerant of shade.	Thrives on poorly drained soils.	Tolerant of cold and wet.	9-12	4.75-5
White-flowering lupin	Fodder and seed crop potential.	Poor yield; not very competitive; winter lupins not recommended in Scotland.	Intolerant of high pH needs high PK status.	Needs dry winters; late harvest.	225 + inoculant	0.71
Peas (fresh or dried)	Potential as cash crop, and animal feed.	Can be difficult to harvest (especially in wet conditions) as very prone to lodging; not very competitive, susceptible to weeds; risk of bird damage; much of fixed N removed in harvested crop.	Prefers free draining soil.	Dislikes waterlogged conditions.	350	0.50
Field Beans	Animal feed.	Easier to harvest than peas but may have lower yield; much of fixed N removed in harvested crop.	Suited to many soils.	Late harvest.	Winter 210 Spring 250	Winter 0.46 Spring 0.47

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