# Cover, Catch and Companion Crops

## Benefits, Challenges and Economics for UK Growers

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AGRICOLOGY

# Contents

# 1. Summary

There is growing interest in early autumn catch crops, over wintered cover crops and companion crop sowing in the United Kingdom. Farmers need to be aware that cover cropping is just one area of an integrated farm management plan and is not a single solution to agronomic problems.

This report highlights the potential **benefits** of cover cropping, from soil structuring, nitrogen recycling, soil erosion and reducing nutrient leaching to help improve water quality. There are aspects of cover cropping that can help weed, disease and pest management. Some of these rely on some natural processes such as bio fumigation, allelopathy and increasing numbers of 'crop pest' predators. Farmland birds can flourish as more diverse food chains are established. Improving conditions and habitat for earthworms and pollinators through cover cropping can also be economically beneficial to farmers. Cover crops can help deliver improvements to ecosystem services through cleaner water, healthier soil and more carbon sequestration. Agricultural policy and legislation has allowed growers to use cover crops in the 'Greening' elements of Cross-Compliance and the management options of Agri-Environment schemes.
The use of cover crops for livestock grazing should not be overlooked as livestock can help with weed, fertility and pest issues.

Growing cover crops is not without **challenges** and following crop yields can be variable. Soil structure and seedbed preparation can be compromised on certain soil types in wet spring weather. Green bridges, slugs and crop diseases can need careful management, but management techniques can be employed to reduce their impact.

The **financial implications** are covered in this report, but more economic studies are required to look at the longer term implications. Further research over a whole crop rotation may reveal benefits of soil health and soil resilience that are not immediately evident in the early stages of cover cropping.

We have included references to **case studies** and the UK Kellogg's Origins Growers group who grew over 500 hectares of cover crops in 2015/16.

# 2. Introduction

There has been considerable interest in recent years **in cover, catch and companion crops**. Primarily grown for **protection and improvement** of both biological ecosystems and crop management, these cover crops can be used continually in long term rotation systems. They have the potential to assist both arable and livestock enterprises by improving soil health and providing valuable fodder and grazing.

Such crops are an integral component of **Conservation Agriculture**, which is a set of guiding principles based on;

1. Minimum soil disturbance through conservation tillage rather than mouldboard ploughing.
2. Permanent plant or crop residue cover (including cover crops).
3. Diverse crop rotations to reduce the need for inputs.

Conservation Agriculture fits into the, soil management, fertility, crop health and production aims of **Integrated Farm Management.**


## Definitions

Cover crops are grown for protecting or improving something on the farm between regular crop production (usually autumn/winter).

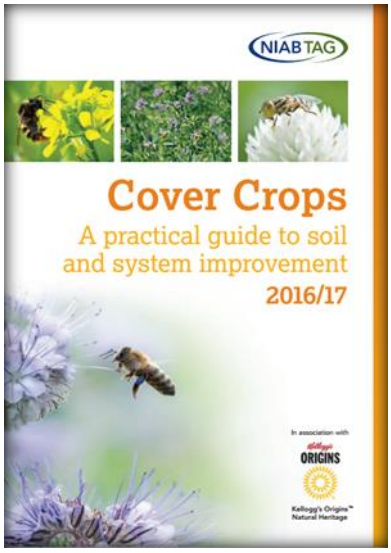
Catch crops are a fast-growing crop that can be grown between successive main crops to provide soil cover, organic matter, rooting structure and in certain circumstances provide some livestock grazing (usually 6-10 weeks).

Companion crops are planted with the main crops for pest control or pollination, provide nutrients, or act as a nurse crop and can help to increase crop productivity.

***In this report, the use of the term cover crop applies to definitions of cover and catch cropping. Companion cropping will be highlighted where specific examples are used.***

## Growing Cover Crops

This report does not go into the detail of practically growing the crops and choosing mixtures, but a good starting place is the NIAB TAG Cover Crop guide as shown below. It includes crop mixtures, sowing dates and rates, establishment, destruction and management of inputs, NIAB TAG (2016).




https://www.agricology.co.uk/sites/default/files/NIABTAG%20Cover%20Crops_lowres.pdf

Selection; Cover, catch and companion crops have different properties, making selection essential for success. It is important to **consider what you are striving to achieve** by implementing this cropping system. There are a range of targets to choose from, including managing weeds and pests, environmental goals such as creating habitat, mitigating nutrient loss along with reducing soil erosion, building soil fertility and improving soil structure. These basics are core ingredients of an Integrated Farm Management Plan (IFM).

Cover Crop Sowing Date; Timings to sow cover crops relies on varieties but should be sown as soon as possible and left for as long as possible. Typically, they are drilled in late August and early September and take around 8 weeks to grow. This post-harvest, early sowing is essential as temperature and moisture levels are critical for cover crop establishment.

Soil Type and Seedbed**;** It is also important to consider soil type, cover crops can be grown on all soil types, but crop selection is key. The tilth created after cover cropping can create the opportunity for direct drilling and reduced cultivation, therefore reducing soil compaction and healthier soils.

Species and Variety; Where nitrogen (N) fixation, nutrient recycling, pest and disease control are concerned species selection is crucial. Different varieties, e.g. legumes, have different capacities to fix or absorb large amounts of N (Lorin et al, 2016). Variety choice within species can also offer differing degrees of benefits to cover cropping and rotational issues.

Fertiliser; Nitrogen application for cover cropping is not essential but can help with quicker crop emergence and will depend upon variety.

Destroying Cover Crop; Destruction methods will vary and must be timed carefully, the later it can be done, the greater the impact of rooting and organic matter will be. Options include grazing the crop, flailing and spraying. There is increasing pressure on the use of glyphosate and this active ingredient is a major part of many cover cropping systems. Those that don't rely on it tend to use ploughing and cultivated stale seedbed techniques.

Following crop sowing; Soil conditions and drill type can be crucial areas for successful establishment of the following crop. Too much cover crop material can block certain drills and damp conditions can inhibit free flow of cover crop residue, especially with early morning dew.

Economics; The integration of cover crops into cropping systems can bring economic benefits. Costs of adopting cover crops include, increased direct seed and starter fertiliser costs, however, they may have potential nitrogen savings on following crops. With the long term improvement of soil structure, cultivation costs may decline, yields improve and external environment be protected and enhanced.

| | LEGUMES | BRASSICAS | GRASSES & CEREALS | NON-MAIN CROP SPECIES | BIOFUMIGATION CROPS |
|---|---|---|---|---|---|
| **CHARACTERISTICS** | -Nitrogen fixing.<br>-Improve soil structure through rooting.<br>-Frost resistant.<br>-Rapid growth. | -Provide good ground cover.<br>-Deep rooting.<br>-Nitrogen catching.<br>-Frost resistant. | - Quick to establish.<br>- Nitrogen catching.<br>- Strong autumn growth. | - Varying rooting properties.<br>- Beneficial to pollinators and insects.<br>- Quick to establish. | - Pest and disease control. |
| **PLANT** | - Clovers.<br>- Black Medick.<br>- Vetch.<br>- Peas and Beans. | - Mustard.<br>- Radish.<br>- Rape.<br>- Turnips. | - Spring or winter oats<br>-Black oats.<br>- Rye. | - Linseed.<br>- Buckwheat.<br>- Phacelia.<br>- Sunflower.<br>- Borage. | - Sticky Nightshade (Nematode Control).<br>- Chicory.<br>-BCN resistant oil radish.<br>- White Mustard. |
| **BENEFITS** | -Raise soil fertility.<br>-Can provide grazing opportunities. | -Rapid growth.<br>-Fit with established farming systems and equipment.<br>- Can be grazed. | -Early ground cover.<br>-Vigorous rooting improving soil structure.<br>- Can be grazed. | - Disease tolerance.<br>- Vigorous rooting improving soil structure.<br>- Phosphate mining. | - Reduced pesticide use and resistance. |
| **CHALLENGES** | -Seed can be expensive. | -Can encourage slugs.<br>-Choose brassica to avoid rotational disease issues. | - Timing of destruction to prevent grasses from seeding.<br>- Risk of take-all if wheat is used as a cover crop mix. | -Can be difficult to control in following crops. | -Cover crop agronomy. |
| **CONSIDERATIONS** | - Autumn sown seed to be established in Jul/Aug.<br>-Tend to be slow growing and can be expensive to establish. | - Autumn pests can be a problem (e.g: slugs).<br>-Can be spring sown. | - Not as deep rooting but will provide soil structure benefits.<br>- Low establishment costs. | - Can be spring sown.<br>- Seed cost can be high. | - Variety choice can have significant. |
| **CROPPING USE** | - Cover.<br>- Companion. | - Cover.<br>- Catch. | - Cover. | - Catch.<br>- Cover.<br>- Companion. | - Cover.<br>- Catch. |

# 3. Benefits

Cover crops can present a whole host of advantages. In simple terms the main aims and results are as follows:

- Improved soil health, structure and organic matter (OM) with potential for increased yields.
- Improved nutrient recycling.
- Reduction of soil erosion and improved water quality.
- Pest, disease and weed control.
- Improved biodiversity.
- Environmental enhancement through agri-environment and cross compliance.
- Livestock grazing.

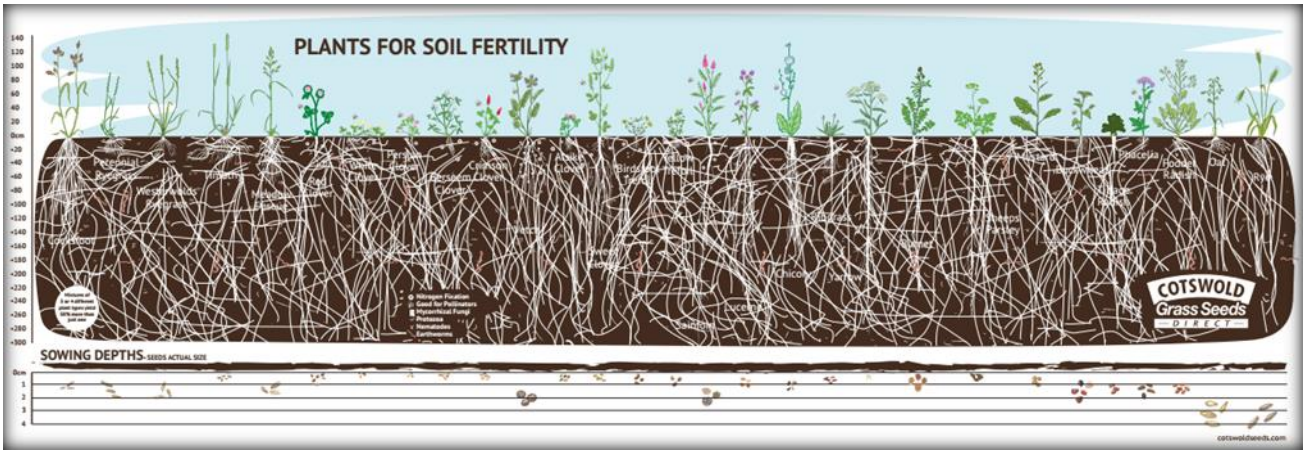
## a. Soil Heath

### *Soil Structure*

Cover crops can deliver improved soil structure at a range of depths and can be used as green manures. The crops improve the **ability of roots** to explore the soil profile to find nutrients. Selecting cover crops with deep rooting abilities will improve soil structure as the roots break through compacted soil (Frontier, 2015).

Cover crops can be very useful as "living plows" by breaking up compacted layers in the soil. Some of the covers, such as sweet clover and forage radish, have roots that reach as deep as three feet in the soil within one cropping season (Clark, 2012). The action of numerous strong taproots can penetrate soil where a plough won't go. Grasses, with their extensive root systems, may relieve compacted surface soil layers. Sorghum sudan grass can be managed to powerfully fracture subsoil (Clark, 2012).

***Grower Tip;*** *The infographic below (from Cotswold Seeds) shows different crops rooting depths, so soil structure at different depths can be addressed.*



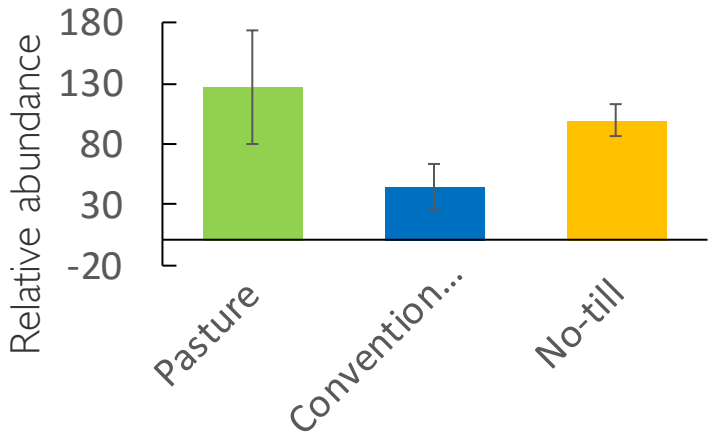

Soil structure can also be improved by the activity of **earthworms** and other soil biota. Cover crops, minimal/ no-till cultivations and previous crop residues (left in the field) can provide favourable conditions for earthworm numbers (see graphs below).

J van Groenigen et al. 2014, presented data which shows that positive differences in plant growth occur when earthworm numbers are 400 or more. This paper states that, *"on average earthworm presence in agroecosystems leads to a 25% increase in crop yield and a 23% increase in aboveground biomass. The magnitude of these effects depends on presence of crop residue, earthworm density and type and rate of fertilization".*

At the Allerton Project our earthworm counts in four of our mixes ranged from 600-800 as shown in; a combination of cover cropping, reduced tillage and previous crop's chopped straw were the contributing factors. However, there appeared to be no statistical difference in their abundance between mixes 1-4.

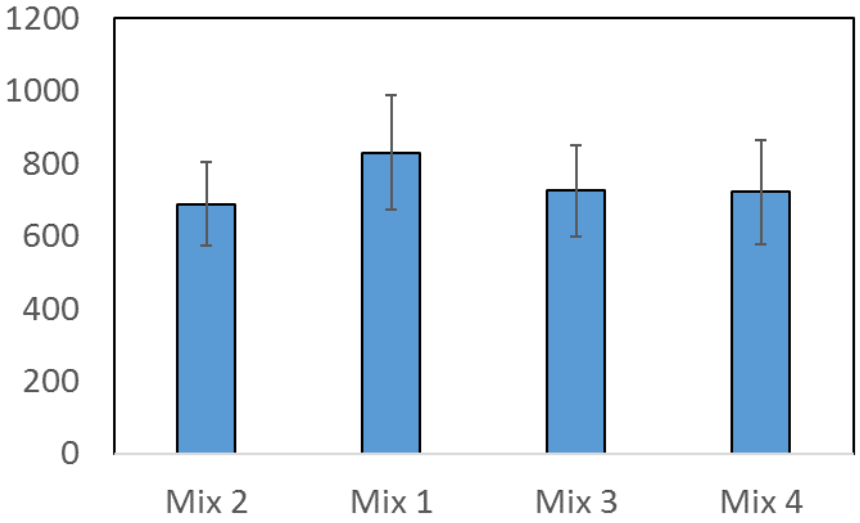
***Grower tip**: Over 400 earthworms per metre squared equates to roughly 16 worms per spade.*

Relative earthworm abundance in pasture and arable cultivation practices.




*Source: Allerton Project, 2015.*

Spring earthworm abundance in cover crop mixes.



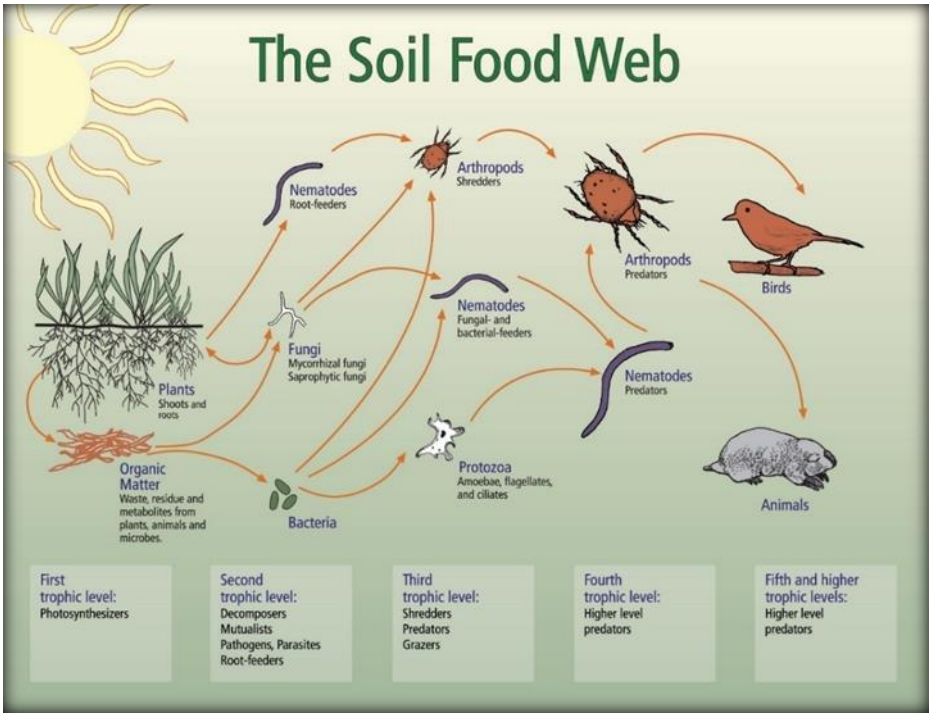

*Source; Dr Felicity Crotty, Allerton Project, 2016.*

| Mix Number | Mix contents |
|---|---|
| 1 | Tillage radish, Oil radish, rye, oats and Phacelia |
| 2 | Mixed oats and Phacelia |
| 3 | Crimson clover, Burseem clover, oats, radish, Phacelia, buckwheat and vetch |
| 4 | No crop (control) |

## *Organic Matter*

Cover crops harvest sunlight to quickly produce green biomass at large volumes, this helps to improve organic matter (OM). **OM is essential for soil biota to thrive**, such as fungi, earthworms, insects and microorganisms. Soil health and crop production are aided by the presence of soil biota through the breaking down of OM to release nutrients gradually (Ingham, 2016a, Frontier, 2015). By creating the right environment for OM production, nitrogen levels will naturally increase in the soil simultaneously due to the cover crop's ability to capture nitrogen.

Organic matter additions drive soil food web dynamics, N availability and plant growth (Ferris and Matute, 2003).




*Source; Ingham, 2016b.*

The benefits of OM include **improved soil structure, increased infiltration and water-holding capacity, increased cation exchange capacity** (the ability of the soil to act as a short-term storage bank for positively charged plant nutrients) and more efficient long-term storage of nutrients (Frontier, 2015). Without OM, there is no soil to speak of, only a dead mixture of ground-up and weathered rocks.

Different plants leave behind different kinds of OM as they decompose, so choice of cover crop will largely determine which soil benefits are gained. Plant materials that are succulent and rich in proteins and sugars will **release nutrients** rapidly but leave behind little long-term OM (Clark 2012, Frontier, 2015).

In general, annual legumes are succulent, releasing nitrogen and other nutrients quickly as they are readily broken down, but are not very effective at building up humus. However, using legumes over a longer period can increase soil humus (Clark, 2012). Grains, grasses and non-legumes will contribute to humus production, but won't release nutrients very rapidly or in large quantities as they approach maturity (Clark, 2012). Plant materials that are woodier or more fibrous will release nutrients much more slowly, but will promote more

stable OM, or humus, leading to better soil physical conditions, increased nutrient-holding capacity and higher cation exchange capacity (Frontier, 2015).

Perennial legumes such as white and red clover may fall in both categories — their leaves will break down quickly, but their stems and root systems may become tough and fibrous and can contribute to humus accumulation (Clark, 2012). **Cereal cover** crops produce the largest amount of biomass and should be considered when the goal is to rapidly build soil organic matter. Legume/cereal or brassica/cereal mixtures delivered the most benefits over a wide range of climatic conditions in Michigan, USA (Snapp et al, 2004).

***Grower Tip;*** *Increasing soil organic matter helps soil resilience and provides a better functioning soil in which to grow crops. It is becoming increasingly important with extreme weather patterns and some of the longer-term implications of climate change.*

## b. Nutrient Recycling

Cover crops enable three key areas of nutrient recycling to be addressed;

- Availability of Nitrogen, Phosphate and Potash for following crops.
- Increase soil microbial activity by influencing the Carbon to Nitrogen ratio.
- Reduction in nutrient loss through erosion and leaching.

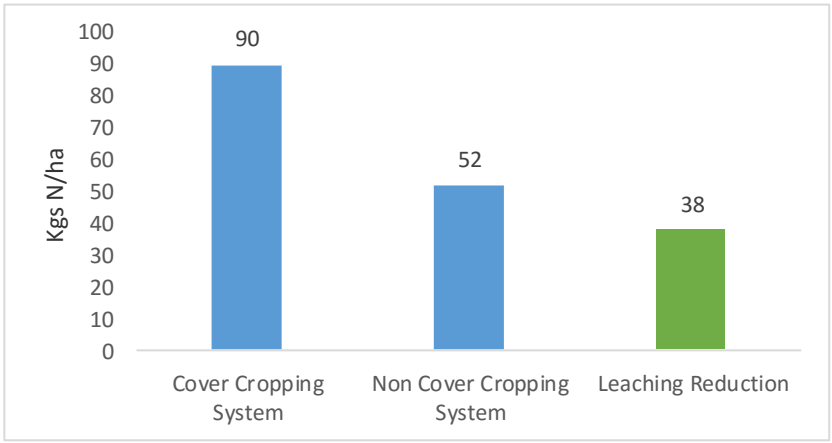
### *Nitrogen, Phosphate and Potash*

Where cover cropping can be used as a legume living mulch, biological N will be provided. Winter frosts can kill cover crops, and provide a valuable resource of nitrogen for mineralisation via fixation or absorption for the following crop (Lorin et al, 2016). The same decomposition will happen when a non-selective herbicide is used to destroy the cover or catch crop.

Legumes are advantageous because they can fix nitrogen from the atmosphere and recycle it through the plant to be readily available for a following crop. Most other cover crop plants absorb plant nutrients from the soil through the roots.

In 2015, a group of Kellogg's Origins growers conducted some field trials on cover crop systems over 6 locations. Cover crops included tillage and oil radish, phacelia, oats, vetch, rye, winter beans, black oats, burseem clover, lupins and peas. The average nitrogen retention from the Cover crop system was 90 kgs/ha which was 38kgs more than the non-cover cropped areas.

Nitrogen retention in cover crop v non cover cropping systems



*Source, NIAB TAG 2016*

Companion cropping nutrient recycling studies have shown that under-sowing winter oilseed rape with frost-sensitive legume living mulch has resulted in N mineralisation from legume residues. The introduction of a legume has been shown to increase N fertiliser recovery (Lorin et al, 2016). Root architecture of the non-legume species may differ between intercropping and sole crop situations (CorreHellou and Crozat, 2005; Hauggaard-Nielsen et al, 2001). This could result in higher N use efficiency from both mineralisation and fertiliser applications (Cadoux et al, 2015).

Intercropping with leguminous crops can result in a significant increase in nitrogen accumulation in rape (Lorin et al, 2016). An increase on 20-40kgN ha-1 was found in common vetch, faba bean, berseem clover, lentil grass, pea fenugreek, field pea, grass pea, common vetch and lentil (Lorin et al, 2016). Nitrogen mineralisation from legume mulch can be greater where the soil mineral nitrogen was low prior to sowing. Intercropping of leguminous crop has also resulted in an improvement in nitrogen fertiliser recovery which in turn improved nitrogen nutrition in the rape crop (Lorin et al, 2016).

Buckwheat is useful at scavenging phosphorous and potentially improving its availability to following crops (NIAB TAG 2016).

### *Soil microbial activity and carbon to nitrogen ratio*

Cover cropping can act as a green manure and will add organic matter and nutrients back into the soil. By providing a green manure, biota will have a feeding source and subsequently stimulate biological activity (NIABTAG, 2015).

Cover crops take in nutrients and convert them into plant material which will become available to following crops in the rotation. Research has shown that cash crops grown following cover crops, specifically legumes, can take up to at least 30-60% of nitrogen produced by cover cropping (Clark, 2012).

Nutrient recycling is dependent on the Carbon: Nitrogen ratio in the soil. Microorganisms living in the soil have a ratio of about 8:1 but microbial activity is ideal when the diet ratio is 24:1. The composition of cover crops and the maturity will give different ratios, but fundamentally the higher the ratio the longer it takes for the crop residue to be broken down. Oats and wheat straw for example has a ratio of 80:1, Peas straw 29:1, rotted farm yard manure 20:1, oil radish 20:1 and legumes vary from 10-12:1. Growth stage of the crop will alter this ratio with rye being 26:1 at the vegetative stage and 37:1 at flowering. The C:N ratio of remaining crop residues will determine the rate of mineralisation of N accumulated by the cover and then N availability to the following crop (AHDB,2016). This can also be affected by thickness of the crop cell lignin. It has also been reported that cover crops may have the most impact on nitrogen availability in the first year of a rotation. In general, the release of nitrogen after a cover crop will be more likely where the C:N ratio is lower (Clark, 2012). As described in the previous paragraph, ratios are affected by crop type and variety. Brassica covers gave a higher C:N ratio than legumes and cereals have the highest C:N ratio (AHDB, 2016).

Legumes have been found to fix nitrogen, producing high quality but limited amounts (0.5–4 Mg ha−1) of residues and can enhance beneficial insect habitat (Snapp et al, 2004). Legumes have been found to be the most reliable means to enhance cash crop yields compared with fallows or other cover crop species. Legume cover crops can serve multiple functions in agro-ecosystems, including suppressing weeds, increasing soil organic matter and increasing nitrogen (N) availability from biological N2 fixation (Schipanski & Drinkwater 2011).

Cultivation methods will also affect the rate of nitrogen mineralisation. It has been reported that in a plough based system compared to direct drilling without a cover crop; the speed of N mineralisation had little

difference respectively, however direct drilling reduced the impact of nitrate leaching by 8kg/ha/yr compared to a plough based system (Laurent, 2006).

***Nutrient loss through erosion and leaching***

The earlier graph in this section about nitrogen retention was equivalent to a 40% reduction in Nitrogen leaching.

Soil that leaves fields via surface or drainage water carries with it nutrients which are better utilised by plants than the potential environmental damage that can occur with high nutrient level entering water courses

***Grower tip:*** *A combination of cover crops in a sown mix will feed soil microbial activity for longer, after destruction, than just legume crops. Reduced tillage will help make soil more resilient as less liable to leaching.*

## c. Erosion Reduction and Water Quality

Cover crop's rooting and ground cover can not only be an active soil structure, but can have the potential to reduce erosion (Snapp et al, 2004). Cover cropping can reduce erosion and run off, especially where soils are fragile and fields are sloping. Catch crops can help prevent water course pollution along with loss of top soil and nutrients. Often if run off occurs it has less soil and therefore less nutrient load.

Autumn and Winter are high pressure seasons when soil moisture and rainfall are high, adopting these types of cropping methods can reduce erosion risk from both wind and water (NIABTAG, 2015). By implementing cover cropping these losses can be reduced and therefore benefit the environment by decreasing sedimentation, soil erosion and leaching, which in turn can protect habitat and water quality (NIABTAG, 2015).

Typically, if more than a third of the ground is covered, erosion risks are considerably reduced, oats and brassicas are recommended for this purpose (NIABTAG, 2015).

At the Allerton Project the introduction of cover crops on steeper sloping land has reduced soil run-off as illustrated below. Heavier soil particles were held in the field by the cover crop and the water run off was much cleaner.

*No Cover - April 2012.*

*Cover crop - February 2014.*

## d. Weed Management

### *Crop competition*

**Cover cropping can supress weeds** and reduce damage by diseases, insects and nematodes. Weed suppression can occur and work successfully as the cover crop (dependent upon variety) smothers and outcompetes weeds for water and nutrients (Clark, 2012). They can also block sunlight and retain soil temperature; brassicas and legumes are especially useful due to their leafy canopy. Cover crops can be used for short term benefit or longer term strategic weed management; these systems are not necessarily mutually compatible.

Long term management requires allowing the pest crop to establish along with the cover crop and before the pest crop can reproduce, both crops are destroyed simultaneously. The weed is reduced year on year. Short term management is when the cover crop is used to supress the weed crop before the sequential crop is sown. Generally, this type of cropping is used to reduce the weed population and seed bank before planting cash crops. Cover crops can provide a "trap crop environment" to reduce seed banks or outcompete weeds to help provide a clean seedbed for following crops.

Legume living mulch is another option used for weed control, especially within Oilseed cropping. This method has been found to decrease weed abundance before winter cropping. Field pea, berseem clover, faba bean and common vetch are particularly effective in all growing conditions. These legumes have been found to decrease weed abundance by 20-75% in the absence of herbicide application (Lorin et al, 2015). The biomass ratio between legume/cash crop can also be a useful indicator. The higher the ratio, the more efficient the weed control (Lorin et al, 2015). However, a high ratio can create a high risk for competition between the cover and cash crop (Lorin et al, 2015).

### *Allelopathy*

*"Allelopathy - The chemical inhibition of one plant (or other organism) by another, due to the release into the environment of substances acting as germination or growth inhibitors".*

There are some differing schools of thought on allelopathic weed suppression by the use of cover crops. One theory is that weed control may be due to 'cover crop root exudates' that stifle tissue growth and act as a natural herbicide. Other allelopathic activity can also inhibit the germination of weed seeds. (Clark, 2012). However, it may be both allelopathy and crop competition, that contribute to weed control. The recent AHDB Research Review addresses a number of areas surrounding this topic. (White, et al. 2016)

It is also possible that a certain amount of **decomposition time** is required after **cover crop destruction** to reduce the impact of toxins, root exudates, pests and diseases on following crops.

Some typical allelopathy areas are:

- Oil radish on blackgrass.
- Blackgrass on blackgrass.
- Cover crop on following main crop i.e. oats following rye.

### *Black Grass Weed Control*

- Some anecdotal evidence of allelopathy from oil radish on black grass exists (Frontier, 2015). Oats and Berseem Clover offers the option of extra nitrogen fixation and soil structure benefits. Black Oats with Common Vetch, are an 'Ecological Focus Area' compliant mix.

- They should be easy to establish and usually in addition to a spring sown cash crop, stable seed bed and two application of glyphosate. Two years of cover and spring cropping trials (Agrovista & Bayer) at Lamport, Northamptonshire, UK reduced blackgrass plants from more than 2000 plant per metre squared to 0.25 heads per metre squared. Winter wheat with full herbicide programme was 274 heads per metre squared and stale seedbeds ahead of spring wheat saw 36 heads per metre squared (CPM, 2016).
- Thick covers can shelter blackgrass from subsequent non-selective herbicide application but can smother and compete with grasses. Growers may need to use non-selective as a pre-emergence spray.
- Thin cover crop establishment will allow more black grass seed germination, but ground cover and rooting benefits from cover cropping may be reduced. Thinner cover crops are probably more preferable to very thick cover crops as encouraging weed seed germination is key.
- The cover crop should mature late to avoid volunteer problems in following crops and should be relatively easy to destroy. NB: Remember late destruction of cover crops can cause late harvesting of following spring, so early maturing spring crops may help in this area.
- Spring crops such as barley may have a wider range of grassweed herbicides available than oats which can give pre-emergence grassweed control.

Such blackgrass control approaches are much more effective if other holistic measures are in place. These include good drainage, machinery hygiene, diverse rotations including temporary grass leys, delayed autumn drilling, increased seed rates, narrower row spacing and vigorous growing cash crop varieties. These management practices should give herbicide programmes the best chance of successful weed control.

**Grower Tip;** Achieving good blackgrass control relies on a holistic management plan, but germinating as many seeds as possible is crucial, so a medium cover crop density is preferable to thick crops where weed seed germination may be compromised.

## e. Disease Management

Cover cropping can reduce reliance upon pesticides and thus cut costs, chemical exposure and protect the environment/the risk of water contamination (Clark, 2012). By including cover crops within a rotation and not spraying insecticides, beneficial insects are often already there before planting spring or summer crops. However, by fully incorporating cover crops into the soil, you destroy or disperse most of the **crop pest predators** that were present, so non-inversion tillage may be worthwhile. Cover crops left on the surface may be living, temporarily suppressed, dying or dead and as such helps increase beneficial predator activity within this habitat (Clark, 2012).

Intercrop effects on diseases include the dilution effect, physical barrier effect, and the chemical effect, which can all lead to lower disease presence. Intercropping can mean distances between plants of the same species are further which delays disease spread (Howard, 2016).

## f. Pest Management

The presence of predatory Carabid (trapped above and below ground) and Staphilinid (trapped below ground) beetles can help towards biological control of field slugs. Some companion cropping can act as a diversion for crop pests. At the Allerton Project in 2016, Burseem clover, sown with oil seed rape, was subject to heavy slug grazing. The oil seed rape despite being grazed by slugs managed to establish satisfactorily.

### *Biofumigation*

A number of cover crop studies that include nematode fauna investigate nematode-suppressive green manures such as sorghum sudangrass, rye, and mustards (Abawi and Widmer, 2000; Wang et al., 2006a; Machado et al., 2007; Collins et al., 2006; Everts et al., 2006).

With increasing pressure on insecticide active ingredients, from both an environmental viewpoint and pest resistance, cover crops can provide a solution. The natural processes of decomposition of cover crops after destruction leads to the release of certain toxins, in brassica cover crops (isothiocyanates) are harmful to soil born pests. (Larkin & Griffin, 2007) and have been shown to help control beet cyst nematode*, (*Hauer *et al.* 2016) and potato cyst nematode in potatoes (Ngala et al. 2015). Brassicas produce glucosinolate, containing residues (2–6 Mg ha−1) and can suppress plant-parasitic nematodes and soil-borne disease (Snapp et al, 2004).

## g. Biodiversity

### *Pollinators*

Autumn sown cover crops often don't flower during the winter period and are destroyed in readiness for following spring crops. However, cover crop drilling date can determine whether crops reach flowering before frost and cooler weather decrease their value for pollinators.

*Sown 8th Spetember 2015.*

*Sown 23rd August 2014.*

Some catch and companion crops, such as Buckwheat, sown in August and September can flower within weeks of sowing (see picture below with bees using early autumn flowering cover crop).

Cover crops can be sown for grazing or for fertility building in organic rotations. In these cases, many of the crops sown will flower and offer food sources for pollinators. Care should be taken not to let certain cover crops produce viable seed that can cause problems in following cash crops.

### *Game and Farmland Birds*

Cover crops can provide winter cover and habitat or a range of wildlife that includes birds, mammals and insects (NIABTAG, 2015).

A study on 'above ground' flying invertebrates showed there is unlikely to be much of a food value for farmland birds in early spring 2016 at the GWCT Allerton Project's Leicestershire farm. However, such invertebrates do play a role in the food chain and by converting organic matter and nutrients into valuable plant resources.

Autumn established cover crops can add value to shoot drives when grown in favourable areas. Some cover crops can provide habitat that offers protection to farmland and gamebirds from raptors. Mowing strips within cover crops can produce flushing points.

## h. Environmental Enhancement

### *Ecosystem services*

Cropping systems that provide ecosystem services are becoming increasingly more important within our rural landscape and are gaining interest from farmers, policy makers and society at large. We still lack frameworks to evaluate and manage for multiple ecosystem services (Dabney et al, 2001). Balancing food production and environmental protection will be instrumental in future UK and European agricultural policy. This may include rejuvenation and enhancement of our environment rather than just protection. Cover crops have been estimated to increase ecosystem services without negatively influencing crop yields (Schipanski et al, 2013). Trade-offs can occur between cover crop ecosystem benefits, production costs, and management risks. Cover crop use will become more economical with increasing fertilizer prices or if modest

cost-sharing programs are established (Dabney et al, 2001). Frameworks such as this can quantify ecosystem services and facilitate the transition to more multifunctional agricultural systems (Dabney et al, 2001).

Cover crops increase soil quality by improving biological, chemical and physical properties including; organic carbon content, cation exchange capacity, aggregate stability, and water infiltrability (Dabney et al, 2001). Legume cover crops contribute N to subsequent crops. Other cover crops, especially grasses and brassicas, are better at scavenging residual N before it can leach. Because growth of these scavenging cover crops is usually N limited, growing grass/legume mixtures often increases total carbon inputs without sacrificing N scavenging efficiency (Dabney et al, 2001).

Cover crops may provide agricultural managers with effective tools to aid soil functionality and help deliver better ecosystem services. In particular, helping to produce more resilient soils, which are less vulnerable to erosion and lead to cleaner surface and ground water that will meet the aims of the Water Framework Directive. The use of cover crops becomes much more effective when used in conjunction with an Integrated Farm Management Plan.

### *Cross-Compliance*

Cover crops can help to meet requirements for our current good agricultural and environmental conditions (GAEC) 4,5 and 6.

- GAEC 4; Minimum Soil Cover.

Minimum soil cover can be provided by cover crops along with leguminous and nitrogen fixing crops.

- GAEC 5; Minimum Land Management reflecting site specific conditions to limit erosion.

Measures must be taken to reduce soil and bankside erosion which can be carried out through cover, catch and companion cropping strategies.

- GAEC 6; Maintenance of Soil Organic Matter.

Cover crops can be used for this purpose as discussed earlier in this chapter.

### *Agri-Environment*

Greening – catch and cover crop option - Ecological Focus Area

To count as an EFA in 2016, catch crops must be;

- Established by **31 August 2016**.
- Retained until at least **1 October 2016.**

To count as an EFA in 2016, cover crops must be;

- Established by **1 October 2016.**
- Retained until at least **15 January 2017**.

There are no restrictions on the management of catch or cover crops outside these periods. However, farmer's EFA areas should not be sown with the intention of being used for harvesting or grazing.

The cover does not need to be destroyed after these periods and it **can be grazed outside of them**.

SW6 - Mid and Higher Tier option (£114 per hectare).

This can be carried out as part of a rotation especially where cultivated land is vulnerable to nitrate leaching or cultivated land that drains directly into a watercourse (Gov.UK, 2016). Cover crops help to reduce nitrate leaching on land that may normally be left bare or in over winter stubble. It can also reduce the risk of potential pollutants entering nearby watercourses.
This SW6 cover crop must;

- Establish a quick-growing cover crop by **15 September** that will provide a dense cover and protect the land from soil erosion and runoff (Gov.UK, 2016).
- Can be **destroyed in late January or early February**, a maximum of 6 weeks before establishing the following spring crop (Gov.UK, 2016).
- When weather conditions delay establishment of a spring crop, the cover crop **can be left until mid-March** (Gov.UK, 2016).

However, this option does not permit the use of any fertilisers or manures.

## i. Livestock Grazing

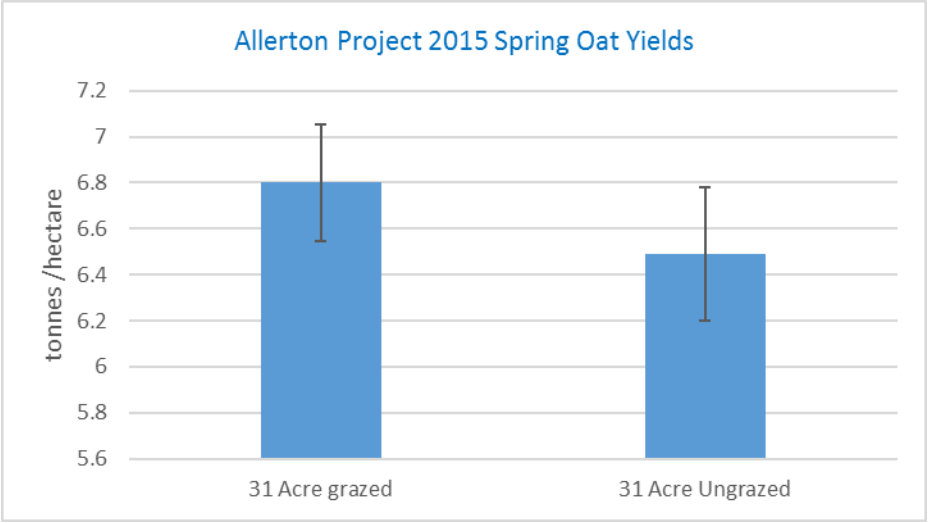
The benefits of cover crops for livestock and mixed farming enterprises are as follows;

- Additional forage area, can be used to flush ewes in a catch crop situation, finishing lambs in autumn/spring on arable fields low in sheep parasites.
- Provides a method of cover crop destruction although, weed and cover crop regrowth can become issues in following crops.
- Recycling of N, P, K from plant material to animal excreta.

***Grower tip;*** ***Careful grazing management is essential to avoid risks associated with soil compaction and nitrogen leaching i.e. choice of grazing regime and soil type that will carry over wintered stock.***

At the Allerton Project grazing mixes were sown on lighter free draining land as shown in the picture below with Mix 8 being grazed by sheep during 4 weeks in February and March.

In the spring of 2015 trails were conducted into the following crop yields in grazed and ungrazed plots. Whilst spring oats yields were slightly higher in grazed plots, there was no statistical difference as shown in the graph below.




*Source; GWCT Allerton Project, 2015.*

# 4. Challenges

Cover crops help contribute to one of the pillars of conservation agriculture; continuous soil cover. Whilst many of the activities within the soil are beneficial, growers should be aware of the potential pitfalls.

## a. Soil structure and seedbed preparation

There are many different soil types with differing characteristics within United Kingdom. Heavy clay soils which have a limited amount time on which field operations can take place, due to their waterlogging nature, are usually autumn sown or grass. Lighter soils have their own issues from wind and water erosion to susceptibility to drought; but in the right climatic conditions are workable all year. Soils that are lighter and loamier usually lead to more even establishment, as drainage and seedbeds conditions are more favourable. It is paramount that timely cover crop destruction and spring crop drilling is practiced on heavier soils. Whilst

the numerous benefits are listed earlier, cover crops can lead to delayed spring cultivations and drilling. Soil moisture is trapped within the soil surface leading to slotted and smeared seedbeds, this can undo many of the targeted soil structure benefits. Drilling can be delayed by up to a month which can be detrimental to yield. Some of these problems can be minimised by early destruction of cover crops in November through to January, which allow the soil to dry out before embarking on fieldwork.

## b. Following crop yields

One potential challenge is the living mulch, this can occur after cover cropping and may compete with the cash crop. It would be fair to say that growers throughout the UK have a wide yield variation in following crops, much of it down to soil type and climate. Chapter 5 covers management of cover crops in terms of economics, but it would be prudent to mention that some studies can give rise to yield losses. The living mulch during the main phases of yield component establishment, particularly during the spring (Lorin et al, 2015), have contributed to these. These variations in yield may be because of the following issues.

## c. Green bridges

With one of the components of Conservation Agriculture advocating 'permanent plant or crop residue cover', there are both strengths and shortcomings of this approach. The main benefits have been covered earlier in the report. However, the green bridge that allows both pests and diseases to survive is a concern to growers. This is an inherent risk in mild winters when a cereal based cover crop is grown ahead of wheat, barley and oats. Cold winters naturally kill aphids so the green bridge effect is reduced. The same is true for certain fungal infections of cereal crops.

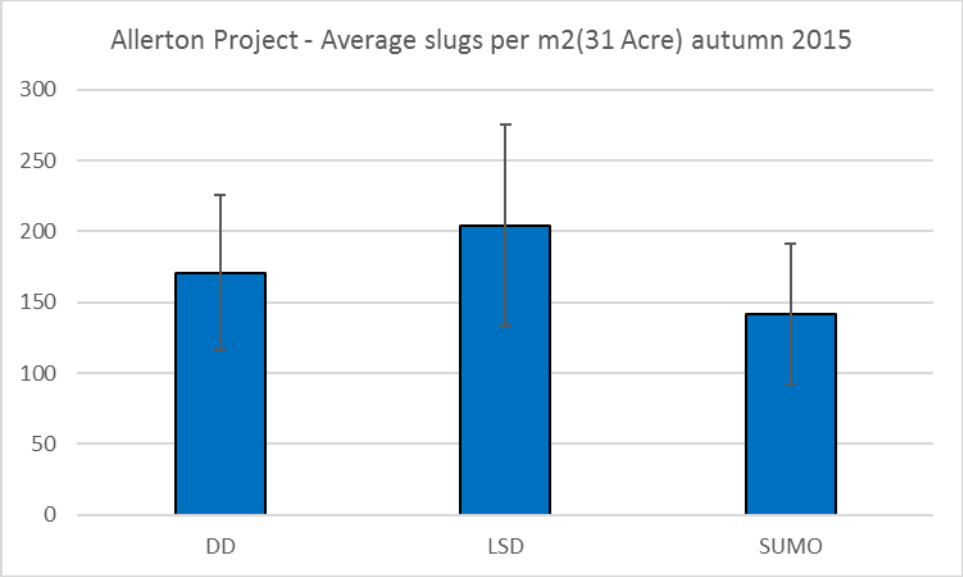
***Growers Tip;*** *The solutions are often farm specific, multi-species mixes can reduce disease and pest build up. Growing varieties of catch, companion and cover crops that are from different families to the cash crop will bring benefits and reduce disease incidence, e.g. Linseed, buckwheat and phacelia.*

*Early desiccation of cover crops and a small period of fallow before cash crops can reduce pest and disease risks but still maintain the erosion, structure and nutrient benefits.*

*Encouraging crop pest predators in field margins, hedges and ditches can help, as can a more selective insecticide spray. As more active ingredients are withdrawn, this type of approach is becoming more limited.*

## d. Slugs and non-beneficial pests

Whilst striving for increased earthworm activity and other beneficial soil activity, other less desirable pests may become more prevalent. These can include molluscs, aphids, nematodes, frit and gout fly. The graph below shows high slug numbers, at the GWCT Allerton Project, in winter wheat crop following cover crops.




*Source; Dr Felicity Crotty, Allerton Project 2015*

Slugs tend to thrive on brassicas in a rotation, and cover crops may encourage higher populations. There are management techniques which can help combat slugs and snails after cover crops.

***Grower tip;*** *Slug Control.*

- Reducing brassica content of cover crop mixture.
- Ensure good soil coverage and well rolled fields to slow mollusc movement within seed bed.
- Pre-bait with slug pellets before wheat drilling.
- Seed dressing with Deter.
- Deeper seed depth up to 50mm for winter wheat.
- Encourage Carabid Beetles. See Biological Control of Crop Pests (Elliot T & Jarvis P.E. 2016).

Cover crops provide valuable habitat for insects especially certain predators, this can complement pest management strategy (ADHB, 2015).

***Grower tip;*** *Killing the cover crop well ahead of drilling reduces the risk of carrying pests, such as aphids, over into the following crop (CPM, 2016).*

## e. Crop Diseases

The most common legume species in cover crop mixtures are vetches, but others are used, such as clovers, medics, lotus, sainfoin, and fenugreek. Pathogens in the soil such as foot rot (*Fusarium*, *Phoma* and *Aphanomyces*) are generally thought to infect a wide range of legumes. There is evidence to show that foot rot (*Aphanomyces euteiches)* from vetch tend to infect vetch and not pea, while foot rot from peas are specialist (NIAB TAG, 2015). Specific care should be taken **introducing brassicas into a rotation containing oil seed rape.**

However, some kinds of footrot (*fusarium*) are known to infect pea, clover, medics and vetches. For example, *sclerotinia trifoliorum* can affect different types of clover in the autumn, causing a 'crown rot', and sclerotia will form over the winter as a result. This *Sclerotinia* species will also infect winter beans, so any build up in a cover crop could create a reservoir of 'sclerotia' fungi which may germinate in following years and infect beans (NIAB TAG, 2015).

Downy mildew is another major pathogen of legume crops in the UK, but fortunately in they are very specialised types which do not cross infect between legume species. Attempts at NIAB to infect pea and field bean with downy mildew from vetch have proved unsuccessful and downy mildew on clover (Peronospora trifoliorum) is a separate species which does not infect either pea or field bean.

The leaf spotting diseases (*chocolate spot, Ascochyta leaf and pod spot, Mycosphaerella leaf and pod spot*) have some specific risks to consider. Vetches can be infected by the chocolate spot pathogen (*Botrytis fabae*), which may increase the risk to field beans either in neighbouring crops or subsequently in the rotation. The leaf and pod spot pathogen (*Mycosphaerella pinodes)* on peas in wet seasons, does have a wider host range, including vetches and clovers (NIAB TAG, 2015).

Cover crop material will usually be incorporated into land, reducing the threat of disease spread by air. Cover crops are usually short term, so soil-borne disease build up may be reduced, but in the case of longer term covers e.g. six months, containing legume species, it will be advisable to follow a three-year break before a grain legume crop is sown, as soil-borne pathogens may have built up (NIAB TAG, 2015).

**Grower Tip;** *Closer monitoring of peas and beans in fields which have had a cover crop before the cash crop may also be advisable so that prompt action can be taken for disease control. Given the value of cover crops in rotations, it is important to get these risks in perspective, and understand how to manage them. Legumes are typically only part of the mixture, so other species such as cereals and brassicas will tend to dilute the leguminous disease pressure.*

## 5. Costs and Returns

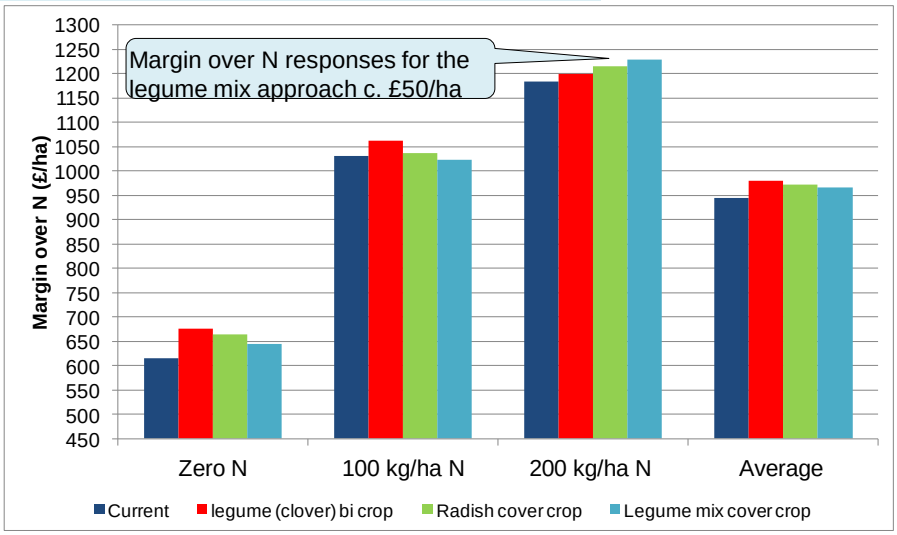
Direct financial benefit of cover cropping is often measured by **yield improvement** in the following crops in the rotation. However, longer term cover crop benefits as described in Section 3, may result in reduced costs, better **gross margins** and **increased profitability**.

**NIAB TAG** have assessed research covering yield and margin response in work with Kellogg's Origins farmers and the New Farming Systems Research (NFS) project: long term research seeking to improve the sustainability and resilience of conventional farming systems (The Morely Agricultural Foundation, JC Mann Trust). The following results have been highlighted;

- Spring barley after an autumn sown legume over a five-year period. Responses were found to vary in individual seasons, however a resulting mean yield increase between 0.28 -0.36 t/ha was found for spring barley succeeding a legume cover crop. This was achieved using standardised nitrogen application at 150kg/ha for the barley.
- Wheat yield responses in 'no N applications' of 14% and to 1.7% where a full N programme was used.

- Increases in margins over Nitrogen of between £50-65/ha (see figure below) in wheat crops after cover crops of clover bi-crops, brassicas or legumes.

**Margin over N in winter wheat (2015)**
NFS data comparing current practice, a white clover bi-crop, a brassica cover crop or a legume mix cover crop.



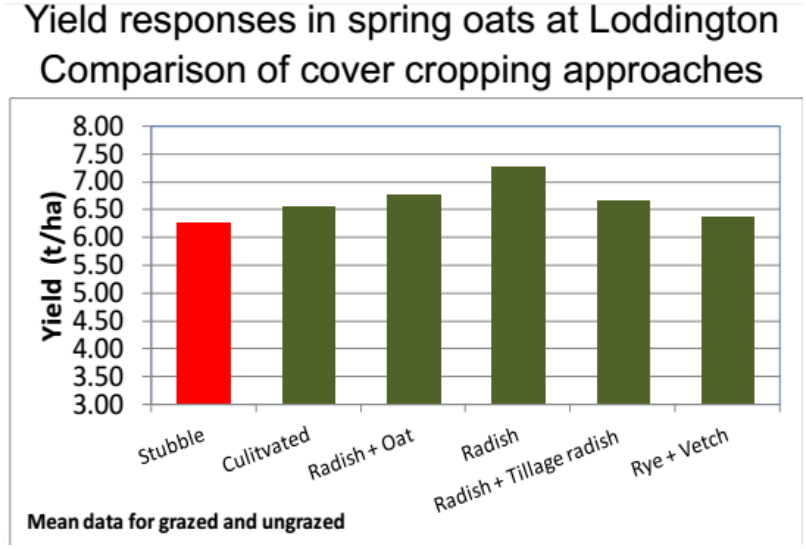

Based on spot prices at the time of production of £120't for winter wheat and £0.67 kg N.

Source: *NIAB TAG for Kellogg's Origins, 2015.*

- Positive yield responses in 5 of the 7-year trial of between 3-10%, the negative yields were between 2-5 %.
- Increase in wheat gross margins in 2012 of £52/ha in shallow non-inversion tillage and £16/ha in plough based system – wheat £175/t, diesel £0.68 per litre, Nitrogen at £0.85 of N per Kg (Stobart & Morris, 2014).
- Increase in wheat gross margins in 2015 of £47/ha in shallow non-inversion tillage and £20/ha in plough based system – wheat £120/t, diesel £0.64 per litre, Nitrogen at £0.67 of N per Kg.

At the **GWCT Allerton Project** between 2014-2016, a number of cover crop trials have been put in place. Some of the financial results are as follows;

- Seed costs have varied from £15-60/ha.
- Establishment varied from £44-70/ha for direct drilling and £50/ha for auto-seeder behind low disturbance tine.
- Increased spring oats yields varied from +0.25t/ha after oats and oil radish cover crop to +0.75t/ha after straight oil radish. With oats at £110/tonne this gave a yield increase of £27.50 and £82.50 respectively.

- 


**Kings/Frontier** *"Guide to cover crops"*

- Oil Radish
  Seed at 17kg/ha costing £40/ha plus drilling and rolling costs.
  Returns; 70kgN/ha captured = approximately £55/ha

***Grower Tip;*** *Cover crops are becoming an integral part of arable and livestock systems. Attention to detail in choice of species and variety are paramount to gain the tangible physical benefits of crop rotations. As more research is undertaken on 'yields and margins' following cover crops, growers can use this information to gain the economic benefits required for sustainable profitable businesses.*

# 6. Case Studies

## Kellogg's Origins Farmers Cover Crop Demonstrations

The Kellogg's Origins programme has developed a unique collaboration between end users, researchers and farmers, all with an interest in using cover crops to improve soils, fertility and other 'Natural Heritage' objectives. NIAB, working with other Origins partners, including the Game and Wildlife Conservation Trust (GWCT), European Food and Farming Partnerships (EFFP) and others, have collaborated with the farmers and Kellogg's to set up, assess and report on this unique series of on-farm cover crop studies.

During the 2014/15 season the Kellogg's Origins programme worked with nine Origins growers to set up a series of on farm cover crop approaches featuring grasses, brassicas, legumes and other cover crop types (e.g. boraginaceae); these were used both as single species and in mixtures. Brassica species (e.g. radish) tended to be associated with some of the greater biomass scores and higher winter survivals, with cereals (e.g. oats) also among the more consistent performers in terms of overwinter survival across a range of sites. Legume species generally had lower levels of biomass and poorer winter survival rates, although this was quite variable between sites. Of the other cover crop types examined, phacelia (a boraginaceae), tended to be intermediate to the previous two types, while some cover crops (such as buckwheat) showed very little cold tolerance and had very low levels of winter survival. Assessment of N in the soil and cover crop systems taken on selected sites also indicated that cover crops reduced the potential level of nitrate leaching compared to bare fallow; on average over the sites the reduction was around 40%, although there was appreciable variability between locations. The reduction achieved will be influenced by level of inherent risk and the crop growth, but the 40% figure would be in keeping with data from other wider research.

## AHDB Fact Sheets

**The New Farming Systems (NFS)** research programme is an ongoing series of long term and fully replicated field studies. The programme is funded by The Morley Agricultural Foundation (TMAF) and The JC Mann Trust and is being carried at Morley (Norfolk, UK) on a sandy loam soil (Ashley series).

The systems evaluated featured a range of cover cropping approaches, including the use of long term clover bi-crops, brassica cover crops and legume mix based cover crops (used ahead of spring sown crops in the rotations). Results show some reduction in oilseed rape yield associated with repeated brassica cover crops use, although to a lesser degree than would be expected from short oilseed rape rotations. However, the use of cover crops has generally shown positive yield responses in winter wheat and this highlights the importance of long term studies to quantify the responses across farm rotations and systems.

The incorporation of cover cropping into rotations has the potential to contribute to agricultural production and to deliver wider benefits to future farming systems.

• Findings show some reduction on oilseed rape yield associated with repeated brassica cover crops use. The research also suggests some interaction between the yield reduction and cultivation system; with greater reductions being associated with inversion tillage.

• The range of cover cropping options assessed differ in their management requirements and likely end results. The choice of species should be guided by particular circumstances and the desired goal.

# 7. Conclusion

- This report covers the benefits of cover cropping, but **careful management** of slugs, blackgrass, pests and diseases will be required.
- The improvements to soil health are evident, however it may take many years to see the full effects.
- Increased margin, as a part of profitability, should be a measure for a sustainable arable system. This analysis needs to be conducted over a number of years or a full crop rotation.
- Growers should be aware that **cover crops form one element** of an **integrated arable system** and require a range of management techniques depending on soil type. There are other components, some of which are shown below, that will help achieve the 'sustainable intensification' many commentators feel global agriculture needs to achieve.


# 8. Acknowledgements

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