

**Cover Cropping
for
Tillage Farming in Ireland**

Nuffield Farming Scholarship Report

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”The importance of permanent soil cover is something that has to be repeated again and again”

Rolf Derpsch (2003)
World Congress on Conservation Agriculture

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*Dust blown from agricultural lands surrounding Sydney partially hides Sydney Harbour Bridge
23rd September, 2009*

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Introduction

I am currently working with my father, Eddie, on the home farm near Kilkenny in the South East of Ireland. We grow winter crops consisting mainly of winter wheat and oilseed rape.

Since 2003 all our arable land has been changed from the conventional plough based tillage to minimum tillage. I am impressed by the positive impact minimum tillage is having on our farm. Our soil has become easier to manage, there is an obvious increase in earthworm and micro-organism activity, and our fuel consumption has reduced significantly.

The Thematic Strategy for Soil Protection was introduced by the European Commission in September 2006. A follow up to the Water Framework (Nitrates) Directive of 2001, which was aimed at improving water quality, the Soils Directive will have as its central objective the improvement of soil quality. It is argued that failure to protect soil is undermining sustainability and long term farm competitiveness throughout the Union.



Slide 1: *The soil sample on the right was taken from a continuous tillage field while the soil sample on the left was taken from the base of the hedgerow in the same field less than 5 metres away.*

Soil degradation has a major impact on other areas of common interest to the community such as human health, food safety, climate change, water quality, and natural biodiversity protection. Soil Degradation is now estimated to cost EU Member States €38 billion annually (EU Commission, 2006). The implementation of a Soil Directive will attempt to reverse decades of soil degradation and erosion that have taken place throughout

Europe.

One important soil protection practice, on arable land in particular, is the use of cover cropping during fallow periods. It is now understood that cover crops not alone provide protection for soils but also contribute to a wide range of desirable agronomic benefits

including improved soil structure, nutrient cycling, weed suppression and disease and pest control. If we were to embrace the concept of cover cropping as a strategy for soil protection on agricultural land in Ireland and the UK we could also benefit financially as well as environmentally.

My Studies & Travels

In conventional farming systems, few growers practice routine incorporation of green manures in the rotation. However as farms become more specialized and less mixed, there needs to be a greater focus on organic matter content particularly on continuous tillage land. The Irish Department of Agriculture has identified a critical soil organic matter level of 3.4% (2% Soil Carbon) below which significant serious soil degradation will happen in a temperate climate. For those whose soil results are below this critical level a range of management practices will have to be implemented, cover cropping being one of them. With the help of the Nuffield Scholarship it was possible to investigate what was been done in the other European countries to ensure compliance with the Nitrate and Soil Directives by growing cover crops and to see if these practices could be adopted under Irish and UK growing conditions. France, Germany and Denmark were visited where in depth interviews with farmers, agronomists and researchers were conducted.

France

I began my study in Rambouillet, due west of Paris, and visited several farmers in the region. Here a cover crop is established immediately after harvesting the main crop and is used primarily to reduce nutrient leaching from the soil profile. Recommended plant species used for nitrate conservation in France are mustard, radish, clover, rye, sorghum, nejar and vetch. Ryegrass is sometimes used.

In France government legislation dictates that farmers must have forty percent of their land grown with cover crops over the winter months if they operate spring cropping systems.

One farmer I visited on the banks of the river Seine was a recipient of a regional subsidy for using cover crops to eliminate the loss of nitrate leachate from the soil. He was growing mustard to catch residual nitrogen in the soil and vetch to fix nitrogen from the air. Most nitrate leaching occurs during the autumn and winter months when fertilizer applications have exceeded the previous cash crops' requirements. Nitrate loss from the soil can be minimized by growing a winter green cover to mop up residual nitrogen.

Jean Luc Marc another arable farmer in the Seine region; he had few soil problems with soil organic matter level ranging between 4 & 5%. But he still spoke passionately about the importance of feeding the soil every year.

An annual or perennial crop can, through its above ground parts and roots, supply between ten and twenty tonnes of dry matter per hectare. In time, this additional organic matter leads to an increase in humus content of the soil, which in turn has a number of positive effects;

- Helps maintain soil structure
- On lighter soils organic matter improves water holding capacity and on heavier clay soils it improves workability and trafficability of the soil
- Provides a nitrogen supply as organic forms of nitrogen are mineralised
- Gives wider windows for cultivation and greater flexibility in the type of cultivation possible.

The contribution of organic matter to the soil from a green manure cover crop is comparable to the additional of nine to thirteen tonnes per acre of farmyard manure – between 4.5 and 5.5 tonnes of dry matter per hectare. Approximately 5.5 tonnes of crop residue per hectare annually is considered adequate to maintain organic matter at constant levels in continuously cropped soils. This figure will of course vary according to climate, region and cropping system.

Nitrogen produced from legumes is a key benefit of growing cover crops and green manures. Research has shown that some leguminous crops used for winter cover and provided that these are sown by mid September can fix up to 200Kg/Ha of free nitrogen for use by the following spring crop. The canopy of the green cover produced protects against rain-induced erosion and while enabling water to infiltrate the soil and drain effectively through the soil profile. Conditions that encourage good nitrogen production include timely sowing, achieving a good plant stand, optimum soil nutrient levels and soil PH, good nodulation and adequate soil moisture.

Arvalis Experimental Station – Boigneville



Slide 2: Arvalis Crops Institute in Boigneville Experimental Station

The portion of green-manure nitrogen available to a following crop is usually about 40% to 60% of the total amount contained in the legume. Research carried out in Arvalis research station in Boigneville has estimated that 40% of plant tissue nitrogen becomes available. The first year following a cover crop that is chemically killed and used as a no till mulch. It is also estimated that 60% of the tissue N is released when the cover crop is incorporated as a green manure rather than left on the surface as a mulch. Lesser amounts are available for the second and third crop following a legume, but increased yields are apparent for two to three growing seasons.

To determine how much nitrogen is contained in a cover crop, an estimate is needed of the yield of the above ground herbage and its percentage of nitrogen.

Cover Crop	Yield of Biomass T/Ha	Yield of Nitrogen Kg/Ha
Sweet Clover	4.3	148
Vetch	4.3	136

Table 1: Dry matter production in legume cover crops grown in France.

The procedure involves taking a field sample drying it, weighing it, and sending a sample off for forage analysis, which includes an estimate of protein content. Once the protein content is known simply divide it by 6.25 to obtain the percentage of nitrogen contained in the cover crop tissue. Finally to obtain Kgs of legume nitrogen per acre, multiply the nitrogen figure by the Kgs of bio-mass figure (Table 1).

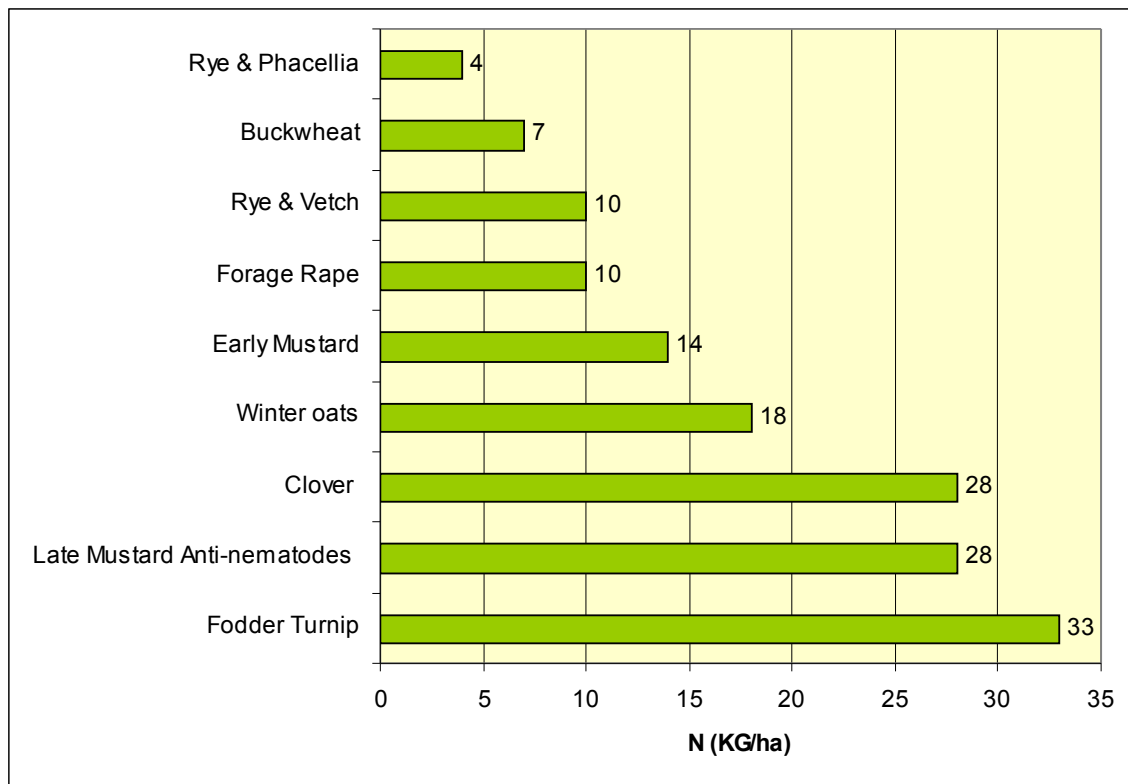


Figure 1: Nitrogen uptake in different cover crops following 2 months growth

While in Arvalis research station I spoke with researcher Jerome Labreuche who is investigating various aspects about cover crops. One of his aims with growing cover crops is to protect and preserve soil structure for the following crop by using the cover crops root system. Other aims are to limit the erosion by keeping the remains on the surface and reduce the leaching of nutrient. A lot of work has been conducted on choosing the right crop. Various combinations including N-uptake ability, soil type, winter rainfall, next crop and crop resistance must be taken into consideration when choosing the right crop for a given field situation. Some species grow only until the first hard night's frost but grow very well under the summer heat. Radish, rye, phacelia and clover are all susceptible to frost kill while, for example, some varieties of mustard are winter hardy.

The cost of cover crop seed is another prohibiting factor with phacelia, vetch and clover proving the most expensive. Oats have consistently been the cheapest cover crop. Mustard and radish provided the best weed competition while rye grass was largely ineffective. Both mustard and radish were also most effective in reducing nitrogen loss through leaching while vetch and clover were least effective. Mustard and vetch gave the best yield result in following spring barley crops due to a combination of all the above factors and the ability of the vetch to fix nitrogen.

One fascinating discovery that is being monitored at present relates to a soil borne fungus called take-all (*Gaumannomyces Graminis L.*). It was found that if a mustard cover crop was grown between two succeeding winter wheat crops, that during the break down of the cover crop molecules that contained sulphur are released and these in turn release isothiocyanates. This molecule seems to slow the development of take-all which has a positive impact on cereal yield,

Denmark

I visited Neils Olsen a tillage farmer based on the middle island of Funen who had been growing cover crops to reduce nitrogen leaching. He had many combinations such as yellow mustard, winter oilseed rape, white clover and red fescue.

In one of his fields he had drilled 140Kg/ha of spring barley including 6Kg of red fescue-seed. After harvest the straw is removed and the field left without further cultivation. The red fescue will grow up and cover the ground and the process will start all over again. The net result of this spring barley-cover crop duo-culture is that yields have stabilized with steady increases of between 500 and 1000Kg/ha being consistently recorded annually when compared with the conventional system. He believes that there is a great difference in structure, especially on heavy clays, between soils that have an under sown ley and those without.

Neils is also experimenting with red clover and has found that autumn tillage is considerably easier on fields with an under sown red clover crop. Red clover has a large and coarse root system that splits up the furrow. The clover is sown with a fertiliser spreader when the main crop is around 10cm high. The crop is sprayed with herbicide before under sowing. There have not been any yield reductions in the cereal crop because of the clover. The clover doesn't compete and it only has a minimal effect on combining. The farmer was adamant that he was now using fewer cultivation passes due to improved soil structure and was spending less on chemical nitrogen due to the improved nitrogen content in the soil.



Slides 3 & 4: *On the left a Swiss farmer sows maize directly into standing turnip rape in Berne Provence and the maize crop is shown on the right growing through the desiccated rape cover(Photos: Dr. W.G. Sturny)*

During my studies I came across a novel use of cover crops being practiced in Switzerland. In Berne Provence a soil protection scheme subsidises the use of cover crops over winter. Here a farmer had sown a crop of turnip rape in the autumn after harvesting winter wheat. The crop was allowed develop right through the following spring and the farmer then sowed a maize crop into the standing cover. The rape was subsequently desiccated with glyphosate allowing the maize develop without further competition.

The extensive root system of various cover crops is highly effective in loosening and aerating the soil. They act like a biological plough in penetrating compacted soil during fallow periods. The rooting depth of different cover crops grown under temperate conditions is shown in Table 2 below.

Cover Crop	Depth in Meters
White Clover	0.3-1.0
Common Vetch, Mustard, Rape	1.0-1.5
Red Clover, Lupin, Radish	1.5-2.0

Table 2: Typical Rooting Depths for Various Cover Crops

US scientist and researcher, Dr. Greg Moyt, discovered that cover crops with their deep



root systems take up nutrients in the subsoil and these nutrients are distributed to the surface soil layers when the plants are ploughed in. Buckwheat and lupins are noted for their ability to enhance phosphorus and potassium availability in soil. Other crop nutrient interactions are shown in Table 3 below. All plants capture significant quantities of nitrogen during their first stage of growth. Crucifers are the most rapid and

efficient followed by phacelia and grasses. Legumes are found to have the best effect when they are mixed with a grass because they can help to overcome an early nitrogen deficiency for the best development of the mixture. A legume will also ensure that there will be sufficient nitrogen in the soil the spring for the next crop.

Crop	Potassium	Phosphorus	Magnesium	Calcium
Vetch	160	22	22	62
Clover	173	20	15	74
Rye	124	20	10	25

Table 3: Typical Nutrient Values (Kgs/Ha) for Various Cover Crops

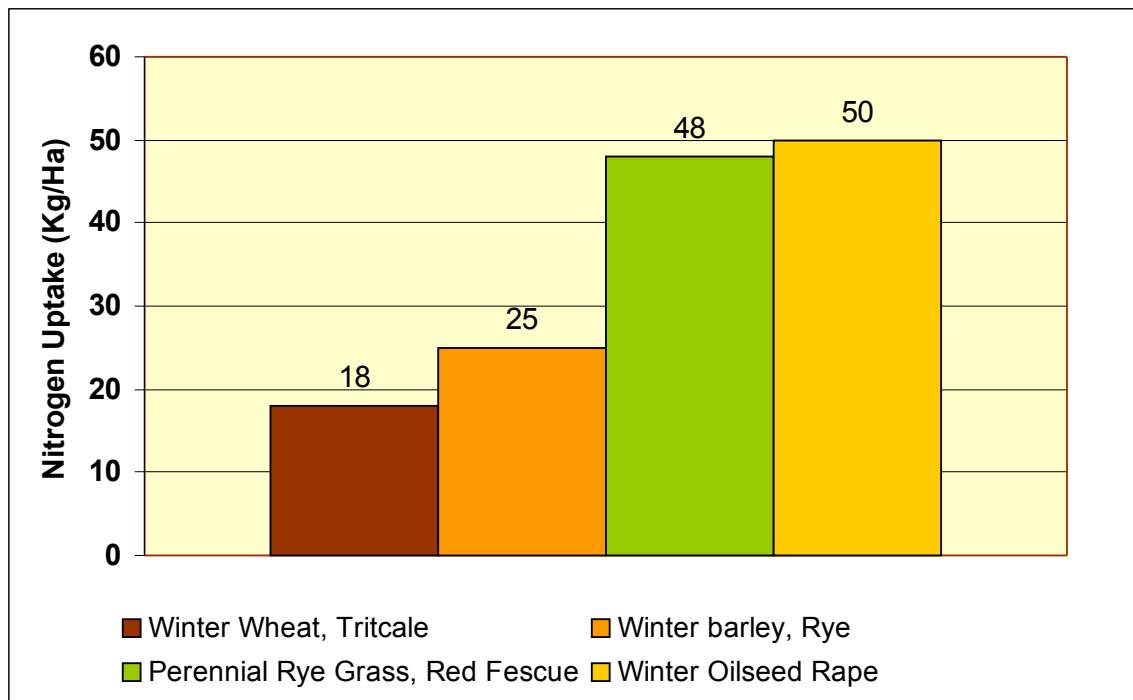


Figure 2: Shows the uptake of Nitrogen by cash crops following different cover crops

Weed Control

Weeds flourish on bare soil. Cover crops take up space and light, thereby shading the soil and reducing the opportunity for weeds to establish themselves. The soil-loosening effect of deep-rooting green manures also reduces weed populations that thrive in compacted soils.

The primary purpose of a non-legume green manure such as rye is to provide weed control, add organic matter and improve soil tilth. They do not produce nitrogen. Thus whenever possible annual grains or vegetable crops should follow a legume green manure to derive the benefit of farm produced nitrogen.

Providing weed suppression through the use of allelopathic cover crops and living mulches has become an important method of weed control in sustainable agriculture. Allelopathic plants are those that inhibit or slow the growth of other nearby plants by releasing natural toxins called allelo-chemicals. Cover crop plants that exhibit allelopathy include rye and summer annual forages related to sorghum.

The mulch that results from mowing or chemically killing allelopathic cover crops can provide significant weed control in no-till cropping systems. Living mulches suppress weeds during the growing season by competing with them for light, moisture and nutrients.



Slides 6 & 7: Rye on the left and Sorghum on the right are examples of allelopathic plants that inhibit and suppress the development of weeds when used as cover crops

I visited the Danish Institute of Plant and Soil Science where experiments were being carried out on ground cover. It was found that the ground cover must not be too dense at the time of sowing to guarantee good crop establishment conditions. This is particularly an issue for spring crops for which a well drained soil and dry surface at sowing time is absolutely crucial.

	Positive Impact	Negative Impact
<i>A: Adds Organic Matter to the Soil</i>	Addition of moderate amount of organic matter More rapid organic matter concentration on the surface	
<i>B: Increase in Soil Fauna</i>	Encourage biological activity- nutrients and more stable growing conditions Indirect impact on soil structure	Encourages slugs especially in cases of abundant residue at time of sowing
<i>C: Residue on the Ground when Crop is Sown (sowing into a cover)</i>	Fragile soils less prone to capping and erosion Reduced run-off and associated leaching of pollutants Reduced moisture loss through evaporation in the spring	Plant residue making sowing difficult (depending on type of drill used) Drying of soil surface slower in the spring Soil warms up more slowly

Table 4: Impact of Cover Crops under a Minimum Tillage System

Ground covers have several advantages, but also some downsides as shown in the Table 3 above. It was found that the presence of plant residue or a cover crop on the ground helps preserve the structure of the soil especially where drought induced cracking is limited - soils containing less than 18% clay or soils which do not dry out in the summer because they are irrigated.

Germany

During spring 2008 I visited Boris Claus, a farmer near Kiel who was, at that time, spraying off an oat cover crop. The oats had grown during the winter months however frost destroyed eighty per cent of the crop in December. Complete desiccation of the remaining oats was made fifteen days before drilling at the end of February by using glyphosate. The drilling was made directly into the residues of the sprayed catch crop, with no previous cultivation.

While the spring barley appeared to get an uneven emergence, Claus mentioned that the result of the barley establishment would probably have been better if the catch crop had been terminated thirty instead of only fifteen days before the drilling period. He concluded by saying that next year he will be careful to terminate all of the catch crops by the end of December or early January to allow the soil time to warm on the surface



Slide 8: *Foreground shows incorporated phacelia in field with standing plants in the background*

and in order to eliminate the plants to improve the drilling conditions and make sure there will be no negative impact on the next crop.

Boris Claus is also doing some trial work with mechanical destruction of the cover crops and is getting some good results. He uses a common land flat roller with bars welded across the drum.

With this he flattens the crop and the bars crush and crack the stems of the cover crop plants. Once the stems have been cracked their decomposition process begins and they can be incorporated in time for the succeeding cash crop. International research has shown that the optimum time for mechanical destruction of cover crops is at or during flowering of the plant.

Carbon to Nitrogen Ratios

Research has shown the factors which influence the ability of micro-organisms to break down the organic matter of cover crops include soil temperature, soil moisture and carbon to nitrogen (C:N) ratio of the plant material. The C:N ratio of plant tissue reflects the kind and age of the plant from which it was derived. As plants mature fibrous plant material, with high carbon content increases and protein (nitrogen) content decreases. Optimum C:N ratios for rapid decomposition of plant organic matter lie between 15.1 and 25.1. C:N ratios above these levels can result in nitrogen being tied up by soil microbes in the break-down of carbon rich crop residues, thus pulling nitrogen away from your cash crop.

Organic Material	C:N Ratio
Young Rye Plants	14:1
Rye at Flowering	20:1
Vetch	10:1
Clover	15:1
Maize Stalks	60:1
Wood Chips	250:1

Table 5: Common C:N Ratios of Cover Crops

Table 4 above shows some typical C:N ratios that can be found in different types of crop residues. The important point is that lush green manures are richer in nitrogen relative to carbon, especially in comparison to highly lignified crop residues like maize stalks. It will take a lot longer for soil microbes to break down maize stalks than fresh vetch and there will be a resultant temporary tie up of available soil nitrogen.

In addition to the soil improving benefits cover crops can also enhance many pest management programs. Ecologists tell us that stable natural systems are typically diverse, containing many different types of plants, arthropods, mammals, birds, and micro-organisms. Growing cover crops adds diversity to a cropping system. In stable systems, serious pest outbreaks are rare, because natural controls exist to automatically bring populations back into balance.

Farmers and researchers in several locations have observed an increased beneficial insect numbers associated with cover crops. The cover crops provide pollen, nectar and a physical location for beneficial insects to live while they search for pest insects.

Ireland

Spring barley generally occupies over half of the arable land in Ireland – an area of approximately 175,000 hectares. Land used for spring barley production is generally left bare after harvest until the ploughing and sowing of the subsequent spring barley crop.

With the absence of cover, nitrate present in the soil is extremely susceptible to leaching. The introduction of the Nitrates Directive(2006) included a clause whereby if ploughing were carried out after the 15th September in any year the farmer would take action to provide a green cover on the ploughed ground with a sown crop within a six week period. While this measure indicated the establishment it was subsequently deemed acceptable that natural regeneration of green material – volunteers or newly emerged weeds – would be sufficient to comply with the measure. Meanwhile in other European countries farmers were actively supported through the provision of subsidy to grow green cover crops during winter fallow periods.

Cover crop research trials have been carried out by Teagasc during 2003 and 2004 in Oak Park Research Station in Carlow on the use of winter cover crops in spring barley production systems in Ireland. The cover crops used in the trial were mustard, forage rape, phacelia, rye oats, westerwolds rye grass, peas and a rye/pea mixture. On the 19th January the cover crops growth had peaked, mustard had significantly more ground biomass than all the other cover crops except rye/pea mixture. Figure 1 & 2 show results obtained from these trials.

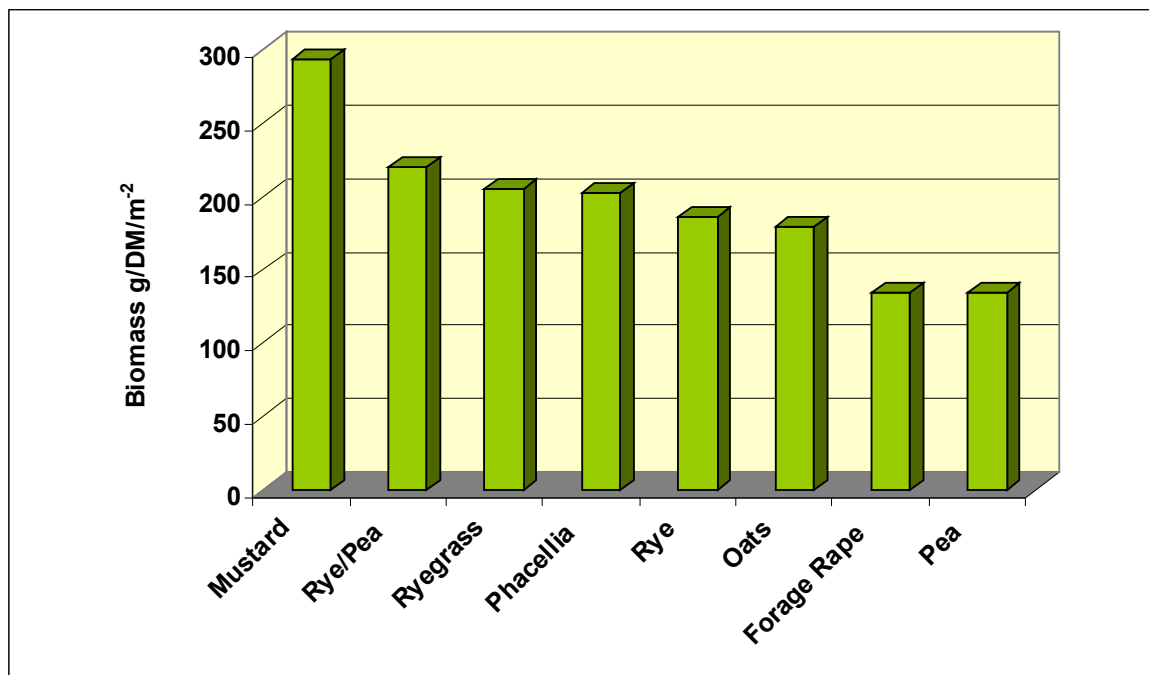


Figure 3 : Above ground dry matter biomass(g/DM/m²) for different cover crops.

Mustard produced the highest level of above ground biomass, had the highest N uptake and was thought to be suitable as an over winter crop under Irish conditions.

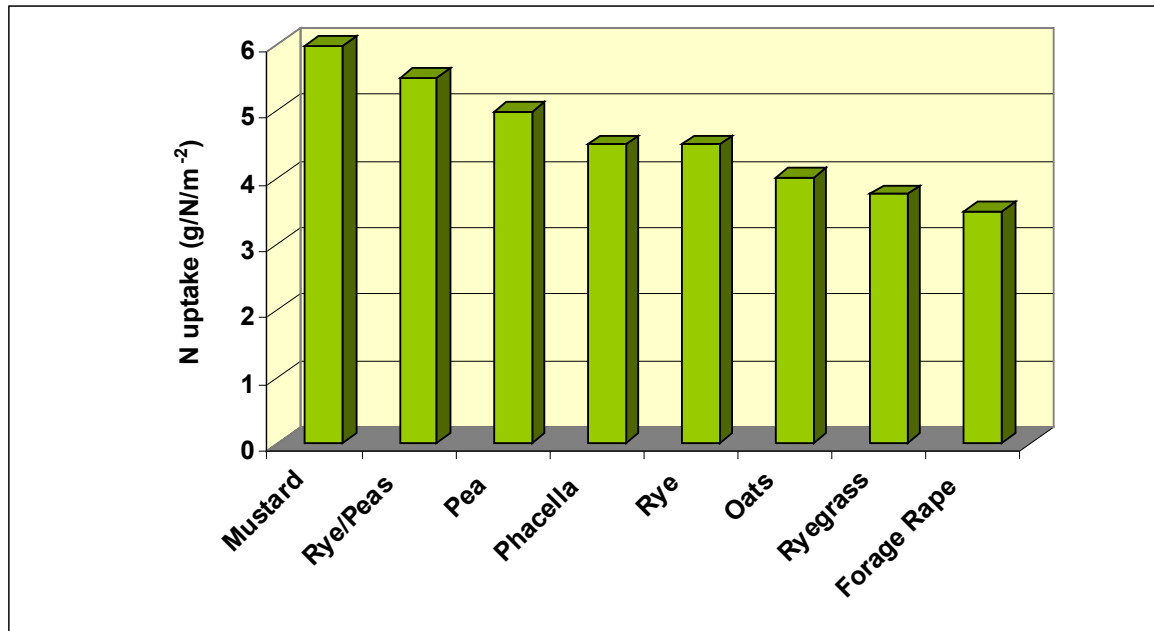


Figure 4: Nitrogen uptake ranged from 3.5g to 5.8g per square metre.

The highest level of nitrogen uptake was from mustard at 58Kg per hectare. In general, treatments with high biomass had high N uptake (with the exception of peas).

Using cover crops over the autumn/winter period when leaching is at its highest has the potential to sequester substantial quantities of N. Other research conducted between 2003 and 2005 at Oakpark evaluated the contribution made by a combination of a cover crop(mustard) with reduced tillage in reducing nitrate leaching.

Over winter cover	2003-2004		2004-2005	
	Reduced Cultivation	Ploughed	Reduced Cultivation	Ploughed
Cover Crop	16.1	28.5	30.9	67.1
No Cover	93.7	71.1	70.0	81.9

Table 6: Summary of the calculated treatment mean annual N load leached (kg N Ha⁻¹) 2003-2005

Over the two years of the trial the highest nitrate losses from the soil were in plots where there was no cover used – both ploughed and reduced tillage. Consistently over the two

years the lowest nitrate losses were using mustard as a cover crop under the minimum tillage system. These results are significant with loss rates of 55 and 51 kilos of nitrogen per hectare – approximately four 50Kg bags of nitrogen fertiliser CAN(27%).

Despite these positive research results there has been little adoption of cover crop growth during winter periods in Ireland. Many of the benefits associated with cover crop usage have never been explained to farmers and there has been little training or promotion of their use by formal extension services. In contrast to observations made in the countries visited there also has been little support provided to Irish farmers by way of subvention to defray seed purchase or crop establishment costs that may be viewed by some farmers as prohibitive.

The provision of promotional grant €25 per hectare of cover crop sown for a three to five year would encourage a change of practice that is frequently identified as being desirable under nitrates, soils and climate change policy initiatives.

Conclusions

In all the countries visited the consistent message was that ‘if soil is not kept covered at all times, and the flora and fauna are not encouraged, the soil will eventually become dead’. Soil protection is of huge importance in eliminating soil erosion and, through the use of cover crops, nitrate leaching can be dramatically reduced. Farmers are only too aware of the problems associated with poor soil management which leads to increased farm costs and reduced profits. Cover crop usage would enhance beneficial soil properties by maintaining and enhancing soil organic matter levels. The prevention of soil erosion and degradation will positively impact on wider society with improved human health, food safety, climate change, water quality and natural biodiversity.

Uptake of cover cropping is beginning to increase throughout Europe, as farmers are actively encouraged through regulation to adopt soil protection measures. In Ireland and the UK cover crops are optional, but in Denmark farmers are required to have 10% of their land area in cover crops if they are in a spring cropping regime and in France they have a 40% rule. In addition to policy developments, the dramatic increase in the cost of fertilizer and other oil based inputs will demand the development of alternative strategies for crop management and protection focused on enhancing economic sustainability at farm level.

There are many organizations in Europe that assist farmers by increasing awareness through training and educational programs. In Ireland the primary support a farmer who is engaged in soil conservation practices receives is through the activities of Conservation Agriculture Ireland(CAIR). All work undertaken by the organization is on a part-time voluntary basis. Otherwise there is a lack of strategic focused initiatives aimed at promoting soil protection through education and support initiatives.

Recent government support for minimum tillage through Rural Environment Protection Scheme (REPS 4) while welcome is totally inadequate. The measure is optional and offers farmers €25/ha while there is little encouragement to grow cover crops under

existing agri-environmental schemes. Representations have been made by the author to Department Officials and some positive developments may arise.

Recommendations

Government support initiatives are urgently required through education and training programmes. Such initiatives need to cater for researchers, advisers and consultants and not just farmers as it is obvious that there is a general lack of knowledge among stakeholders throughout the tillage sector.

The creation of a specific unit to collate, categorise, promote and distribute relevant research information, international agri-environmental initiatives, ongoing farm based practices and developments from other countries is now necessary. Such a unit would be responsible for the co-ordination of aforementioned education and awareness initiatives for organizations and agencies involved in agricultural and environmental developments and services. The annual cost for such an undertaking could easily be catered for within existing Department of Environment or Department of Agriculture Food & Fisheries budgets.

Specific ongoing research is needed on monitoring suitable cover crops for integration with commercial crop production under Irish and UK conditions. Much research conducted to date while useful has been basic, selective and specific rather than comprehensive, holistic and integrated. It is not sufficient to generate data on individual cover crop species alone with no assessment of their impact on subsequent cash crop species and varieties.

Deductions from Single Farm Payments under the modulation system are being made on an annual basis. Funds arising from modulation are supposed to be distributed for sustainable and suitable agri-environmental schemes and measures. It is recommended that modulated funds arising from the tillage enterprises be redirected back to those tillage farmers who adopt good farming practice methods such as winter cover cropping

during fallow periods, the use of buffer strips along watercourses, and reduced soil disturbance through minimum and no tillage adoption.

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