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Commodity Markets – a traders viewpoint

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SUMMARY

The recent rally in the price of grains was caused by factors which are now well understood e.g . economic growth especially in Asia and the Far East where expanding GDP means diet upgrade, higher per capita food consumption and more demand for protein. China remains the main engine with 7-10% GDP growth, changing their diet to oil/fat/meat instead of rice, and contracting forward for energy and minerals, as well as investing billions of dollars in African infrastructure to secure access to raw materials. Other factors such as population growth along with the global rundown of stocks have also played their part.

This year's rally has been led by wheat, where the surprise on the demand side was India who sourced 7 million tonnes of imports when the world was expecting zero to 1.5 million. In the midst of the balancing of this demand versus supply equation a dynamic new entrant to the market has now turned corn into the driver of the cycle – Energy.

George Bush set a target of 7.5 billion gallons of ethanol production for transport fuel by 2012, reflecting about 5% of projected U.S. fuel consumption. Current U.S. capacity is 5.4 billion gallons with another 6.2 billion gallons of capacity under construction!. This total capacity when operative will consume almost 40% of projected US corn production. To meet this supplemental demand the market estimates another 8 million acres of corn must be sown this spring, taken largely from soyabeans – the next cycle driver. Then yield must hit trend levels, even then this potentially translates into unacceptably tight year-end stocks.

In order to bring this situation under control corn has rallied 52% last year. Wheat stands a good chance of rebuilding stocks next year with this year's rally having expanded acreage all around the globe. However wheat will now have to be fed in style to livestock to take the pressure off corn, which will help to absorb that surplus. Although some are starting to question the economics of ethanol in the U.S. with the recent collapse in crude oil prices, one has to remember the political driver behind the ethanol project – self-sufficiency and independence from oil produced in politically unpredictable regimes.

In the EU main the main feedstock will be wheat. The economics of ethanol, are different in the EU. Wheat has less starch and the EU supply/demand is far more balanced – in fact deficit in maize and only surplus some 10% of its 120 million tonne wheat production. The US has a surplus of 40% of its 250 million tonne corn production before ethanol demand is taken into account. Higher feedstock prices in the EU have to be met by even more generous government tax subsidy. This is administered under a loose but committed protocol to achieve 5.75% of transport fuel requirements to be met by ethanol by 2010. However, there will be the inevitable lag in application, which is left to the discretion of the individual member states.

In the coming season world barley stocks will be in over-supply and aggressive competition from Ukraine in early season export markets, even without Australia, will keep the feed barley discount to wheat very wide to enforce maximum take-up in compound rations. Malting barley is a different matter and will continue to make substantial premiums as maltsters struggle to rebuild stocks until well into harvest. However a large crop is in the making given normal weather, and if quality is good those premiums will come down.

Maize prices should maintain healthy premiums to wheat, not least because if prices stay above $4 on corn one can expect exports ex Hungary, Bulgaria and Rumania to third country Mediterranean destinations. As to where price levels work out, that will largely depend on corn world-prices, and this is something we are not used to in the EU. Taken on its own, wheat would not be able to achieve the lofty levels we have seen this year, and benchmark values would be nearer $160 FOB EU for the last quarter compared to the $185 trading now. However the corn market cannot relax until the required acreage is in and successfully negotiated the critical pollination period in July/August. For the moment sentiment and the trend is bullish.

The commodity cycle and food’s part in it

A bull market in commodities in the 40’s was followed by sideways markets through the 50’s and 60’s. The markets went on another bull run in the 70’s with gold peaking in February 1980. Soya beans hit $12 in this period, which was followed by another sideways market up until 1999. Now we have entered a new bull cycle – and depending on which planet one follows the cycle could be part of a 29 or 84 year cycle. This has been led by metals and then crude oil. It is now the turn of Food and especially Grain as the next component of the cycle to move. This will be followed by livestock.

The market has been driven in this cycle by large hedge fund and index fund participation. The Fund interest in commodities has been driven by investment objective elements such as inflation hedging and alternative asset allocation, but also by a basic reading of this cycle. Grain is the current target of their attention. Oilseeds will follow.

Many market players are uncomfortable with the scale of the positions being taken by the Funds, but their participation is set to grow substantially. The demand for commodities as an alternative asset and inflation hedge is on a huge growth path, and there are relatively few products on the market currently to meet investor demand. As the banks and large financial institutions develop new commodity investment products, they bring more and more cash to the market.

Do the Fundamentals support the interest in Grains?

The first part of the rally in grains was caused factors which are well understood now:-

- Economic growth especially in Asia and the Far East. Expanding GDP means diet upgrade, higher per capita food consumption and more demand for protein.
- China the main engine with 7-10% GDP growth, changing their diet to oil/fat/meat instead of rice, and contracting forward for energy and minerals, as well as investing billions of dollars in African infrastructure to secure access to raw materials.
- Population growth.
- Global rundown of stocks, a legacy of low prices.

This year's rally has been led by wheat, and when the headline global supply/demand features are summarized, it's not surprising.

	Expected wheat crop	**Actual**
Australia	25	8
Argentina	14	12
US	43	39
EU	119	108
Black Sea (exports)	16	11

On the demand side the main feature was India who sourced 7 million tonnes of imports when the world was expecting zero to 1.5 million

In the midst of the balancing of this demand versus supply equation a dynamic new entrant to the market has now turned corn into the driver of the cycle – Energy.

Effect of Ethanol as grain demand driver world-wide

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To meet this supplemental demand the market estimates another 8 million acres of corn must be sown this spring, taken largely from soya beans – the next cycle driver. Then yield must hit trend levels, all of which translates potentially into unacceptably tight year-end stocks.

In order to bring this situation under control corn has rallied 52% last year. Wheat stands a good chance of rebuilding stocks next year with this year's rally having expanded acreage all around the globe. However wheat will now have to be fed in style to livestock to take the pressure off corn, which will help to absorb that surplus.

Although some are starting to question the economics of ethanol in the U.S. with the recent collapse in crude oil prices, one has to remember the political driver behind the ethanol project – self-sufficiency and independence from oil produced in politically unpredictable regimes.

Effect of Ethanol as grain demand driver – EU

The EU main feedstock will be wheat. The economics of ethanol, are different in the EU. Wheat has less starch and the EU supply/demand is far more balanced – in fact the EU is deficit in maize and has only a surplus of some 10% of its 120 million tonnes of wheat production. In contrast the US is surplus 40% of its 250 million tonne corn production before ethanol demand is taken into account. Higher feedstock prices in the EU have to be met by even more generous government tax subsidy. This is administered under a loose but committed protocol to achieve 5.75% of transport fuel requirements to be met by ethanol by 2010, which the EU will keep trying to make mandatory. However there will be the inevitable lag in application, which is left to the discretion of the individual member states.

In many ways the effects of the new player in EU markets will be no less dynamic.

a) Trade flows will change. The large compound feed industries in Holland and Belgium were fed by France, Germany, Scandinavia, Belgium and the UK. The UK and Belgian surpluses will be taken out, with resultant higher prices. A significant proportion of the surplus areas in France will also be diverted to ethanol. There will be an increasing reliance on the surpluses in Central and Eastern Europe, as well as the Black Sea producers, all of which have difficult, uncertain and expensive logistics.
b) The ethanol producer can hedge 2-3 years forward, and will be driven to do so by the banks in order to lock in margins on high-cost investments, and due to the imperative for a speedy amortization of their investment. The feed and food producers margin horizon is 12 months in the case of food and 2-3 months in the case of feed. How are these industries to compete with the dynamic buying power of the ethanol producer?
c) The EU will remain surplus grains due to the slow rhythm of construction of the ethanol plants. However since the supply/demand equation is far more balanced, and

with the purchasing dynamics mentioned above, the market will behave deficit for large periods of the campaign, resulting in big price swings and increase in volatility.

d) Liquidity will also become a major problem. There will be times when prices will make exaggerated moves on limited volume. Cool heads will be required to keep one's eye on the ball of real value – but even then end-users may find it hard to maintain the flow of supplies to the plants at that perceived number.

e) It gives the opportunity to kick away some of the corner-stones of the original CAP. For example maize intervention is set to disappear.

Next year's grain prospects

On the world front, as already mentioned, there will be an opportunity to rebuild wheat stocks. World production is set to recover some 40-45 million tones, and wheat will narrow its spread on corn to induce wheat feeding, and spend much of the year as a follower, leaving corn to drive the market

Inside the EU, Brussels has launched a programme this year to liquidate all the intervention stocks they are holding. They will be largely successful in this, with only Hungary still carrying a substantial unsold quantity of some 4-5 million tonnes of maize in a year which will end on bare boards in terms of carry-out stocks. The EU wheat surplus will run between 12-13 million tonnes including Rumania and Bulgaria, and while the EU will have strong competition from the Black Sea, they should ultimately be able to dispose of this. The picture is therefore balanced, but the lack of government-owned stock together with the overall bullish global outlook will make for a steady and well-supported market.

Barley however will be in over-supply. Aggressive competition from Ukraine in early season export markets, even without Australia, will keep feed barley discounts to wheat very wide to enforce maximum take-up in compound rations, and one can't exclude prices having to trade at intervention levels in Eastern Germany, again if all the crops come though well. Malting barley is a different matter and will continue to make substantial premiums as maltster's struggle to rebuild stocks until well into harvest. However a large crop is in the making given normal weather, and if quality is good those premiums will come down.

Maize prices should maintain healthy premiums to wheat, not least because if prices stay above $4 on corn one can expect exports ex Hungary, Bulgaria and Rumania to third country Mediterranean destinations.

As to where price levels work out, that will largely depend on corn world-prices, and this is something we are not used to in the EU. Taken on its own, wheat would not be able to achieve the lofty levels we have seen this year, and benchmark values would be nearer $160 FOB EU for the last quarter compared to the $185 trading now. However the corn market cannot relax until the required acreage is in and successfully negotiated the critical pollination period in July/August. For the moment sentiment and the trend is bullish.

Is the ethanol demand situation irreversible?

Politically this demand bandwagon will not be stopped in the short term. However the market is reacting already with substantial increases in wheat and corn acreage. Seed technology will no doubt follow on and pick up the challenge.

Both the government and the EU have acreage in reserve programmes which can eventually be released, and new land can be commissioned in South America and areas like Russia and the Ukraine.

Some sectors will suffer – notably the livestock sector. Inefficient producers with no access to substitutes such as the by-product of ethanol, DDGs, will be forced out of business, and it is commonly recognized that, although increased use of DDGs and also wheat, hay and pasture will help it reduce demand for corn, the livestock industry will have to cut back in terms of size to make way for the new player.

Longer term, technology will bring on second-generation feedstocks such as switchgrass, miscanthus, straw and other cellulose based crops to take over from ethanol, which, though it satisfies current political imperatives, is an economically and ecologically flawed project. Hence the requirement of ethanol producers to write off their investments as soon as they can.

Commodity cycle – enjoy the ride but recognize the risks

The risks will come from violent price swings hitting constantly higher peaks over the next few years – especially if weather takes a hand.

However corrections could be equally violent and run very deep. Take corn at $4 per bushel now in the U.S which many are touting to hit $5. The CEO of a leading international consultant said in a speech only days ago that if the acreage they project gets planted in good conditions and survives the summer, they expect corn back at $3 in the autumn.

Several large industrials have already felt the effects of the swings we have had this year. One large U.S. industrial announced recently that they were ceasing using the futures market as a hedging medium.

The price swings will be even more dangerous to the extent that view the huge fund participation, unexpected outside events will at times put the market into a state of panic. Crop failures are something the Trade have learned to anticipate. They can be very disruptive and can certainly wreak serious damage, but market liquidity can generally handle them.

How about a global systemic event such as bird flu however? The mere fear of that can have a dramatic effect on sentiment given the current structure of the fund positions. What about Government, who can be every bit as dangerous? President Carter's grain export embargo against Russia in 1980 comes to mind. This was recognized as a bad mistake, but there is no doubt that ethanol will have a seriously inflationary effect on food, and although current attitudes may seem cavalier in this regard, Government will act unpredictably if food supplies become seriously threatened by a series of crop failures. How about a government-prompted order for the U.S. grains futures to trade on a liquidation-only basis?. Index funds are currently long some 400,000 corn contracts, equal to the entire U.S. annual export demand. It is not a concern for now, nor is it too likely in the immediate future, but it has happened!

This volatility will play havoc with the Trade as a whole. Merchants and shippers will have to live with the fact that there will be the inevitable defaults and bankruptcies, and it will be important to diversify one’s commercial distribution across the industrial sector, and monitor exposure to individual trading firms, both in terms of credit risk and market price differences. Farmers will have to exercise the same rigour.

One should not over-dramatise, because the remedies are simple and boring. Although this will at times be scary, the Trade will naturally assume the basic counter-strategy which will have hugely beneficial effects on the industry and on market organisation as a whole. It will be very important to :

a) Know the customer.

b) Diversify sources of supply, and spread sales activity across several industrial sectors.

c) Build a network of individuals and firms in whom one can have confidence, and whose market role can be understood and trusted.

d) Use that network not only to develop mutually acceptable supply chains, but also to operate in relative transparency and with an understanding of each other’s business imperatives.

Finally let´s not ignore or become complacent about the commodity cycle theory. It maybe telling us things we don´t and can´t know.

Commercial Productions of Biofuels

John Mullins, Chief Executive
Bioverda Ltd.

SUMMARY

Bioverda is a wholly owned subsidiary of NTR plc and specialises in the utilisation of sustainable and renewable sources of bioenergy. Bioverda is a natural progression for NTR given its synergy with NTR's existing waste management and renewable energy businesses and Bioverda is focused on two key areas:

Biofuels: Biodiesel and bioethanol. Bioverda is finalising construction of two fully integrated crushing and esterification biodiesel facilities located in Germany. When complete, these facilities will produce a combined total of approximately 250,000 tonnes (284,250,000 litres) of rape methyl ester per annum. In addition, Bioverda is developing large scale biodiesel facilities in Ireland, the UK and Spain. Bioverda is also developing large scale bioethanol facilities in the United States and assessing opportunities in the UK.

Biomass: Bioverda produces 135,000 MWh of electricity generated from landfill gas fuelled assets located on seven landfill sites in Ireland. Bioverda is also developing a number of large scale biogas facilities and is currently planning a 47 MW of large scale waste to energy anaerobic digestion facilities in Ireland.

Bioverda has announced its intention to build a large scale vegetable oil based biodiesel facility in the Port of Cork, Ireland. The development will be located at the deep water port site in Ringaskiddy and will result in the renovation of the site with a renewable and environmentally friendly process. The facility will make use of an existing tank farm and storage area which has a capacity for 50,000 tonnes and which will be refurbished as part of the development and rejuvenation of the site.

It is anticipated that construction of the project will commence within the next 12 months. The plant will have the ability to accept a variety of vegetable oils, a significant portion of which will be locally sourced rapeseed oil. As mentioned previously, the plant will have access to an independent deep water jetty in order to be able to accept economically viable quantities of feedstock vegetable oils. The facility will have a production capacity of 200,000

tonnes (227,400,000 litres) of biodiesel per annum and the strategic storage capacity for vegetable oils will enable it to compete in a rapidly expanding international biodiesel market.

Bioverda is also currently engaged in the process of obtaining full planning permission for the development of a large scale centralised anaerobic digestion / combined waste and power facility on lands under the company's control. The proposed anaerobic digestion facility, located at Ballard in County Cork, is designed to meet a critical infrastructure requirement for the abatement of greenhouse gas (GHG) emissions, renewable electricity generation, and to enable the country to meet a number of recently enacted European Directives.

Challenges facing Bioverda in Ireland

In operating in the renewable and sustainable fuels sector, Bioverda has encountered a number of challenges for developing projects in Ireland as against other countries in Europe and North America. As more and more consumers realise the advantages and prospects of renewable and sustainable fuels, so too have Governments accepted the importance and increasing relevance of the sector. However some of the challenges facing the bioenergy sector in Ireland are outlined below. It is critical that the Government addresses these issues as there is an opportunity cost for companies such as Bioverda developing projects in Ireland as opposed to more incentivised and better regulated markets in other countries.

Biofuels – Bioverda's Take on the Current Situation in Ireland

Current biofuels scheme

In 2005, oil represented 56% of Ireland's total primary energy requirement, all of which had to be imported. As a result of security of supply concerns and climate change mitigation at a wider EU level, in 2003, the EU issued a Biofuels Directive which had a requirement that by the end of 2010, 5.75% by energy content of all petrol and diesel used for transport purposes must originate from renewable sources. As part of this measure, the Directive also required member states to have a biofuels penetration of 2% by 2005.

In order to make biofuels economical for sale relative to mineral petrol and diesel, an amount of excise relief needs to be provided by the government. With this in mind, in 2005, the Irish government set up a scheme to grant excise relief for the production of 16 million litres of biofuels or just over 14,000 tonnes. As a result, eight individual biofuels projects were set up for sale and distribution of the fuel. However, this was not enough to stimulate large scale production and by the end of 2005, the amount of biofuels sold in the Irish market was 0.1%. As a result, the EU issued a letter of formal notice against Ireland. Following this notice, in Budget 2006, Ireland announced an incentive scheme of excise relief to achieve 2.2% fuel substitution by 2008. This took the form of a scheme whereby companies would submit applications to the government for a portion of excise relief, up to a combined national total of €200 million until 2010. The government then picked those companies that it thought would be likely to build biofuel plants based on answers to a questionnaire submitted by companies. This was at odds with a number of other European countries which awarded excise relief to fuel actually sold in the country rather than fuel that was proposed to be sold. For example, in the UK, all biofuel sold is awarded 20p per litre excise relief but unlike Ireland, there is no cap on the amount of fuel that can be awarded such relief. In addition, oil companies will be penalised if they do not blend a portion biofuels in their products. However, from the EU's perspective, because Ireland demonstrated some level of progress towards meeting the 2003 Biofuels Directive, the EU subsequently dropped formal proceedings against the country in April 2006.

In 2006, Bioverda announced that it would be investing €50 million in a new biofuel production facility in Cork harbour. This would complement its existing biofuel developments in the UK, Spain, Germany and the United States. Once complete in 2008, the Irish facility will be able to produce around 200,000 tonnes of biodiesel per year. Subsequently however, Bioverda was not awarded any excise relief by the Irish government. As mentioned previously, the €200 million was awarded to companies based on answers to a written questionnaire. The Department of Communications Marine and Natural Resources (DCMNR) who ran the scheme did not meet with any of the applicants or test the claims made in the submissions. As one of the only applicants with experience in developing and operating biofuel facilities, Bioverda now finds itself in the difficult position of being locked out of the Irish marketplace as it will not be able to sell any of its product without excise relief. As a result, all of the facility's product will be sold in the UK and European markets. Bioverda was not alone however. Of the companies awarded excise relief in the original 2005 Scheme, the majority were not supported in the 2006 Scheme and subsequently are likely to face difficulty continuing as biofuels operators in Ireland. Ireland's existing piecemeal approach to biofuels production means that companies like Bioverda will find it impossible to sell product into Ireland and will be operating in spite of any government assistance rather than because of it.

From a policy perspective, there is a significant danger of concluding that because Ireland is not likely to become self sufficient in biofuels crop production (such as rapeseed), that Irish biofuel targets should not exceed EU minimum targets. It is fundamentally wrong to conclude that biofuel use in Ireland should be equivalent to the amount of biofuels actually produced in Ireland. In the case of biodiesel, it is important to note that given the highly desirable properties of rapeseed oil for cold flow operation as well as its higher value on the world vegetable oil markets, rapeseed oil will always form a key and critical portion of any biofuels mix, with the remainder coming from various overseas supplies such as soya bean oil, sunflower oil and palm oil etc. Therefore, by mixing higher quality indigenously produced rapeseed oil with other potentially imported (and sustainable) vegetable oils, a greater proportion of sustainable and long term biodiesel can be produced in Ireland. This still addresses the key issues of supporting Irish farmers by utilising whatever can be produced in Ireland as well as helping to mitigate security of supply, diversification of risk and climate change issues.

Given the arguments above, Bioverda is firmly of the view that the EU minimum targets of 2% by 2005 and 5.75% by 2010 should be considered by Ireland to be just that, minimum targets. As previously mentioned, it is widely acknowledged that in order to make biofuels economical for sale relative to mineral petrol and diesel, an amount of excise relief needs to be provided by the government in order for biofuels to be sold. As a result, biofuels developers will only be able to sell biodiesel into the Irish market equivalent to the volume of excise relief awarded to them. However, the way the current Biofuels Scheme is designed with a limited amount of excise relief being awarded to specific companies, any additional biofuels produced in Ireland can not be sold in Ireland. This effectively provides a maximum cap on the amount of biofuels that can be sold in the country.

In addition, unless Irish biofuel plants are producing product at a highly efficient and large scale, the portion of biofuel that is not awarded excise relief will not be able to compete effectively in a European context and those facilities will become uneconomical in the medium term. Even with an expansion of the current Scheme, this would not be enough to guarantee any one large-scale facility financial viability. Further, the current Scheme means that projects are unlikely to be able to obtain finance from the capital markets given the high degree of uncertainty behind this particular type of regulatory support Scheme.

It is Bioverda's opinion that the best way to effectively stimulate long term, sustainable and economic liquid biofuels use in Ireland is to place a mandatory requirement on hydrocarbon companies to provide a blend of 5.75% biofuels by 2008/2009. However in addition, the actual target for biofuels use needs to be increased beyond 5.75% and most importantly, the current Biofuels Scheme must be opened to any company who sells biofuel in Ireland. This latter point is of critical importance if Ireland is to grow a long term and sustainable indigenous supply chain and to enable Ireland to compete for biofuels sales relative to its European neighbours.

It is also worth noting that the Department of Transport has committed to integrating sustainability considerations into the development and delivery of transport policy. Sustainability considerations should also form a core part of any biofuels obligation scheme. This is vital if biofuel companies are to be encouraged to source feedstocks from sustainable sources thereby maximising the amount of CO2 savings occurring on a field to forecourt basis. The current Biofuels Scheme does not prevent companies from sourcing low cost, environmentally destructive and unsustainable feedstocks from foreign countries and this needs to be addressed. If this is not addressed in the near future, those companies who source more expensive but sustainable supplies will effectively become penalised in the market as well as insuring that any climate change benefits become negated.

Critical energy infrastructure incentives

If Ireland is going to successfully meet its proposed targets of 15% of electricity production to be met by renewable energy sources by 2010 and 30% by 2020, a number of barriers will need to be overcome. These are barriers that Bioverda has direct experience in while trying to develop energy projects, particularly renewable energy projects in Ireland. Some of these barriers are outlined below:

As an example, as mentioned previously, Bioverda is currently engaged in the process of obtaining full planning permission for the development of a large scale centralised anaerobic digestion / combined waste and power facility in Co. Cork. Such a large scale facility would provide a piece of critical infrastructure in the form of greenhouse gas abatement, renewable energy generation and a large scale alternative and acceptable disposal route for liquid wastes.

Several independent assessments have concluded that large scale anaerobic digestion as a source of renewable energy are difficult to justify as financially viable stand-alone projects. In order to enable this type of project to become economic reality, and in recognition of the climate change and energy security benefits, it is vital that the Government recognises that in certain instances (such as large scale anaerobic digestion), certain projects need additional incentives, for example by using the Kyoto Flexible Mechanisms. These projects could easily be structured so that the credits are issued under the Unilateral Joint Implementation process whereby a portion of the credits are retained by the government and left within the 'budget of allowances'. This would reward both parties, stimulate an investment that would otherwise not necessarily have occurred and encourage a project that is additional to CO_2 abatement measures that would already have occurred.

Planning

Bioverda's experience in developing the anaerobic digestion facility in County Cork has shown that the planning process in Ireland is heavily biased against similar projects that contribute to security of supply and carbon abatement, and could be considered critical infrastructure. Throughout the planning process, the emphasis has been placed on that of waste rather than energy. While Bioverda's point of view is that this project is a strategic renewable energy and GHG abatement facility with significant waste management benefits, the planners are currently forced to take the view that it is primarily a waste facility with some additional energy and environmental benefits.

The planning application system should allow for consultation of the full potential benefits that would be realised from such an energy project. As it currently stands in the planning process, there are no provisions to fully describe the positive effects of such a development. For example, any benefits that may be outlined in an Environmental Impact Statement are site specific and do not cater for the fact that the facility will result in increased security of supply as well as reduction of greenhouse gases.

As previously mentioned, there has been little or no acknowledgement in the planning process of the importance of infrastructure in terms of meeting Ireland's strategic energy requirements, climate change obligations or renewable energy requirements. The Energy Green Paper must take account of these planning matters where they relate to key infrastructure that contribute to energy infrastructure and climate change mitigation. As an example this issue may come under the auspices of the Ministerial Bioenergy Task Force.

Government supported renewable energy projects

In the past the DCMNR has provided support, initially through the Alternative Energy Requirement (AER) schemes and more recently through the Renewable Energy Feed in Tariff (REFIT) programme. Whilst these mechanisms are to be welcomed by generators of renewable energy, Bioverda's view is that:

The 'Reference Prices' for the tariffs are too low to attract investment and should be increased to match those in other parts of the EU for energy generated from renewable sources. In addition the process of assessing applications for inclusion in these schemes can be very lengthy. The period of time from the point of the applicant's submission to the award of the support scheme and subsequently to the point where electricity is commercially exported onto the grid is unduly protracted and requires shortening.

CONCLUSIONS

The above examples demonstrate that currently, it is difficult for a European operator such as Bioverda to justify investing in such renewable energy projects in Ireland as opposed to better supported neighbouring countries in the EU as well as the US. As an Irish company, Bioverda is particularly keen to work with the Government and all Agricultural Agencies to overcome these barriers in order to provide investment in renewable energy infrastructure in Ireland. There is a real opportunity for agriculture to contribute to first and second generation biofuels production in Ireland. This will most probably take a decade to fully implement but it does provide a future for tillage in Ireland.

Supplying the Biofuels Sector

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SUMMARY

The roll-out of the expanded excise relief (MOTR) scheme will lead to some increase in native biodiesel and bioethanol production, but it will also lead to an unnecessarily large amount of biofuel imports; this problem will be exacerbated if Ireland signs up to the higher biofuel substitution targets spelled out in the recent Green Paper and EU Road Map. The fuel pellet market is also growing much faster than native production capacity; here again imports are increasing rapidly. The use of wood chips for commercial heating can develop rapidly, but supply chains to provide good quality chips at suitable moisture content will be needed to satisfy the market. A beginning can be made to the use of biomass in the peat-burning power stations if the necessary adjustments are made to the payment system.

On the one hand it is encouraging to see so many competing energy uses for biomass beginning to emerge. On the other hand, if we are to avoid misdirected investment and minimise imports, we need national policies for the various biofuel sectors which assure a reasonable profit for farmer and processor as well as providing maximum national benefit in terms of land use, fuel supply security and greenhouse gas abatement. In the development of these policies, the voice of the raw material supplier needs to be clearly heard.

INTRODUCTION

The past year has been a turbulent one for biofuel development in Ireland. It began with very high oil and gas prices and budget promises of substantial support for liquid biofuels and commercial and residential heat. The roll-out of these schemes during the year produced some unforeseen results. Grants for biomass boilers have stimulated a demand for chips and pellets that has stretched supply chains beyond their limits. The MOTR allocations disappointed many potential processors of Irish raw materials and seem likely to lead to an unnecessary level of biofuel imports. The weaknesses of the excise relief mechanism is also becoming apparent. In the absence of establishment grants, progress in the planting of perennial energy crops such as willow and miscanthus has been slow. The recent Green

Paper on Sustainable Energy contains some ambitious targets for biofuels development, but we must await the promised Biomass Action Plan to see what measures are to be put in place towards the achievement of those targets (Department of Marine and Natural Resources, 2006). The present fall in oil prices is also reducing profitability prospects for biofuel producers and processors.

Many of these problems have arisen from our attempts to make up lost ground and move forward too rapidly after many years of inactivity. Hopefully the coming years will see a more orderly move towards the development of a biofuel infrastructure in Ireland.

Liquid biofuels

MOTR and 2% substitution target: The most recent MOTR excise relief scheme was designed to achieve a 2% substitution target. If it were all supplied from native feed-stocks it would require the produce of about 75,000 ha of tillage land, i.e. about 20% of our total tilled area. It is not clear at present as to what proportion of the excise relief allocations will be produced from native raw materials, but it is obvious that there will be a large amount of imports.

Green Paper and 5.75% substitution target: The follow-up target of 5.75% in the Biofuels Directive is also set as a target for Ireland in the Green Paper. Originally this was to be achieved by 2010, but considerable slippage from this date may be expected. The Commission's recently published Road Map proposes a target of 10% substitution by 2020 (Commission of the European Communities, 2006). It will be extremely difficult for Ireland to come near to achieving these targets from native resources in the medium-term future, almost regardless of policy initiatives, for the following reasons:

- With present technologies, Irish liquid biofuel feedstocks are confined largely to annual arable crops. The short-term prospects are ethanol from cereals or beet and vegetable oil from rape-seed, with a small amount of tallow and waste vegetable oil.

- To achieve the 5.75% target for both diesel (rape-seed oil) and petrol (ethanol from cereals) would require about 180,000 ha of rape-seed, and 75,000 ha of cereals. With rape in a one-in-four year rotation, this would need 720,000 ha of land in tillage, almost twice the present amount. The inclusion of beet for ethanol production would further exacerbate this problem. The extra tillage land would lead to the production of over 1 million tonnes of additional cereals that would have to find a new market. It would also probably bring us above the 10% reduction in permanent pasture specified in the most recent CAP re-negotiation (Department of Agriculture and Food, 2006).

- If the overall substitution target were met by producing more ethanol and less rape-seed, an area of about 115,000 ha of cereals and 40,000 ha of rape-seed would be sufficient. This would be much more attainable from a land use viewpoint, and more realistic in terms of the required tillage increase. Another option would be to transfer some of the rape-seed area to beet for ethanol production. But any option along these lines would require ethanol substitution in petrol of well above 5% on average. At present, an EU Directive restricts the sale of ethanol for use in unmodified engines to 5% blends with petrol (Commission of European Communities, 1985). Higher proportions could be used in flexible fuel vehicles. But with very few FFVs on the road at present, it is difficult to see how higher levels of substitution could be achieved in the short to medium term.

- A recent report by the European Environment Agency questions the availability of any land in Ireland on which to produce biofuel crops without increasing pressures on the environment (European Environment Agency, 2006). This report takes no account of the demise of the sugar industry, and is based largely on an unreasonable assumption that no permanent pasture should be replaced by biofuel (tillage) crops. Nevertheless, it is clear from the report that any Irish biofuel programme that involved a substantial expansion of the current tillage area would be examined critically by environmental bodies.

- The Irish maritime climate is generally better suited to the production of lignocellulosic (mainly perennial) crops rather than sugar, starch or oil (mainly annual) crops. Eventually it will be feasible to convert lignocellulose to liquid biofuels. Second-generation technologies are emerging for the conversion of materials such as wood, straw or miscanthus either to ethanol or to other petrol or diesel substitutes. However, it will be many years before these technologies reach commercial reality. From an Irish perspective, there is also a concern that the scale required to make these plants viable may be beyond our feedstock production capacity. Finally, it remains to be seen whether the price that could be paid for feedstock for these plants would be attractive to an Irish producer. For the present, we can only await developments.

In the meantime, would it not be better for Ireland to argue for a transport biofuel substitution target not much over 2%, and focus more attention on the use of ligno-cellulose materials for heat/electricity production as detailed below? If the European Commission does not accept this approach, then it is almost inevitable that to meet its Biofuels Directive targets Ireland will be forced to import large quantities of either liquid biofuel feedtocks or processed biofuels. In that case the same cost of excise relief will be incurred, but with no benefit to agriculture and limited effect on fuel supply security. French and German studies have shown that excise relief based on home-produced feed-stocks is largely recouped by the exchequer as additional VAT, income tax etc generated by the additional economic activity. Relief on imported feed-stock or biofuel would cost about €28M per annum per 1% substitution, virtually none of which would be recouped.

Home-produced vs imported biofuels: While it would not be permissible to discriminate against biofuel imports from other member states in the MOTR or similar schemes, projects with short transport distances between feedstock source, process plant and end user should be favoured on the basis of reduction in road traffic and associated road congestion and vehicle emissions. Belgium is working on the inclusion of such measures in its excise relief programme. Biofuel imports from within or outside the EU should be carefully monitored to ensure that every aspect of their production is environmentally sustainable.

Excise relief vs. inclusion obligations: For the promotion of transport biofuels, a variety of mechanisms could be considered (Sustainable Energy Ireland, 2005). Most of the leading EU member states are now beginning to move the emphasis from excise relief to blending obligations, i.e. obliging oil companies to include a certain proportion of biofuels in their annual sales. Eventually a similar move will have to be considered for Ireland. Blending obligations maintain a market for biofuels in times of low mineral diesel prices, but it is a very inelastic market. They would need to be closely matched to native biofuel production capacity; otherwise they will lead to big fluctuations in biofuel prices and stimulate imports. This could damage Irish biofuel production at its present fledgling stage, and might be better deferred until the industry is more mature.

Biofuel quality: The current MOTR scheme rightly puts great emphasis on fuel quality assurance. The growth of a fledgling industry would be seriously damaged by the marketing of low-quality biofuel leading to engine problems. Every producer needs to ensure that all their production meets the appropriate standard (EN 14214 for biodiesel, DIN 51605 for pure plant oil, and in the absence of an agreed EU standard for bio-ethanol, either prEN 15376, ASTM D 5798, ASTM D 4806 or the Swedish Sekab standard). All future support schemes should maintain this quality emphasis.

Biofuel technologies and feedstocks: Subject to the quality requirements listed above, biofuel incentives should not discriminate between biofuel feedstocks or technologies. Actions by other member states to disincentivise the use of pure plant oil in modified engines or the use of tallow as a biodiesel feedstock should not be followed. Possible Commission moves to exclude the use of tallow for biodiesel production should be discouraged.

Solid biofuels

The Bioheat and Greener Homes schemes have generated huge interest in biomass heating fuels; at present this interest is concentrated mainly in three areas:

Commercial heat: The total energy demand of the commercial/public sector in 2005 was 1.8 million tonnes of oil equivalent (Sustainable Energy Ireland, 2006). Heat from oil, gas and coal accounted for over 1 million tonnes of this demand. The most likely biomass substitution in this market is wood chips as boiler fuel. The chips could come initially from forest and sawmill residues and forest thinnings. COFORD have estimated the availability of sawmill and forest residues at about 0.5 million tonnes at present, increasing to 1.3 million tonnes by 2015 (COFORD, 2002). However, as Coillte's timber is subject to long-term agreements, Teagasc figures show that the biggest long-term source of energy wood is first thinnings in farm forests (Table 1).

Table 1: The potential output from thinning from private forests based on 50% of stands being thinned over the period 2006 – 2015

First thinning age	First thinning volume (ktonnes*)	Second thinning volume (ktonnes*)	Cumulative volume output (ktonnes*)
2006	876**		876
2007	194		1070
2008	195		1265
2009	273		1538
2010	369		1906
2011	352	1226	3485
2012	225	272	3981
2013	213	273	4466
2014	250	382	5099
2015	302	516	5917
Total	3248	2669	

* Weight of <u>freshly</u> felled timber

**Analysis assumes that this volume is removed from forests currently aged 15 – 26 in 2006 and 2011.

To meet a market beyond this level, short-rotation willow and miscanthus are among the more likely possibilities. The main problems would be:

1) *The cost of willow production:* An establishment grant will be essential to stimulate development of these crops. It costs approx €2,800/ha to establish miscanthus and €2400/ha for willow. The payback period for these crops is 7–10 years at an assumed price of €60/tonne. Farmers could not be advised to plant either crop in the absence of establishment grants.
2) *Support services:* There is no equipment on farms or with local contractors either for planting willows or miscanthus or for harvesting willows. Farmers or contractors will need some incentive to invest in such equipment to allow an industry to grow to a commercial level.
3) *Drying of willow chips:* Willow chips need to be dried from a moisture content of over 50% at harvest to below 30% for safe storage and efficient combustion. Current Oak Park trials with simple low-cost ventilation systems are expected to provide an answer to this problem.
4) *VAT exemption for planting material:* An exemption is needed from VAT on the purchase of miscanthus rhizomes and willow cuttings. This would reduce the

establishment cost of both crops by over €200/ha, a very significant cost reduction.

5) *Miscanthus boiler:* Many wood-burning boilers would not be suitable for burning miscanthus; a suitable boiler would have to be selected. One such boiler is currently being commissioned at Oak Park; it is bigger and more expensive, but more fuel-flexible than the standard wood-chip boiler.

These fuels are bulky and expensive to transport, so the initial target market sector should be buildings outside urban areas with a big, continuous heat demand, such as hotels or hospitals. Short distances between fuel source and user will be important, so distribution will be very much on a local basis. The development of reliable local supply chains will be a key to success, if heat users are to be persuaded that they can safely change to biomass fuel. Start-up aid should be provided towards co-operative groups setting up supply chains. A comprehensive support mechanism along the lines of the DEFRA Bio-Energy infrastructure Scheme should be put in place (Department for Environment, Food and Rural Affairs, 2006). Local authorities should be encouraged to do business with local supply chains to heat swimming pools, government buildings etc.

Residential heat: The Irish total residential energy demand was almost 3 million tonnes of oil equivalent in 2005 (Sustainable Energy Ireland, 2006). At least 2 million tonnes of this demand is heat from fossil oil, gas and coal. The most likely alternative to these fuels is biomass pellets used in stoves and small boilers. Demand for pellets has exploded since the advent of the Greener Homes Scheme, and this demand is being met mainly by imports.

Sawdust is the first choice material for pelleting. National production of sawdust has been estimated at about 200,000 tonnes (COFORD, 2002), but some of this is already used for energy, e.g. for on-site heating or in CHP units at sawmills, or in the existing pellet plant in Enniskillen. When sawdust supplies are exhausted, wood residues, cereal and rape straw and energy crops such as willow or miscanthus would be other possibilities as feedstocks for pellet production. The high bulk density of pellets reduces transport costs, which will facilitate imports from countries with low-cost raw materials and large production scale. Even allowing for transport costs, home pellet production will need to be very efficient to compete with these imports. Capital grants will be needed to allow a number of projects of a suitable scale to get under way before imported produce establishes a firm hold on the Irish market.

In rural areas, an alternative boiler fuel for heating farm homes is cereal grains. While the heat value of grain is close to that of wood, ignition difficulties, higher ash content and clinker formation present more challenges to the boiler. We need to clarify the relative merits of the various grain species and the maximum moisture contents for satisfactory combustion. Teagasc is currently commissioning one such boiler; others have already been sold to tillage farmers, and any teething problems will be quickly sorted out. Current or new grant schemes for domestic boilers should apply to those burning grain as well as other biomass fuels.

With the Greener Homes grant scheme to alleviate the higher costs of biomass boilers, at present oil and gas prices a change to biomass looks attractive. Substitution of 10% of residential oil-gas-coal use would require at least 200,000 tonnes of oil equivalent, or roughly 0.5 million tonnes of biomass. The achievement of this target would require as much sawdust as can be collected as well as other wood and crop residues and some energy crops.

Electricity generation: The 30% peat substitution target set out in the Green Paper for the three peat-burning stations would require biomass to replace about 0.9 million tonnes of peat. Assuming net calorific values of 8 and 12 MJ/kg for peat and biomass respectively, about 0.6 million tonnes of biomass would be required. Given that commercial and residential demands will develop for wood residues, it is likely that much of the power station demand will have to be met by energy crops.

The selection of suitable energy crops for this purpose will need to be re-examined with a view to providing a year-round supply of suitable material. The most likely contenders are likely to be miscanthus, willow, hemp and possibly reed canary grass. The environmental impacts (biodiversity, hydrology, visual impact etc) of growing a large amount of energy crop close to the power stations would have to be considered, but should be largely beneficial if the right crop mix, site selection and husbandry practices are followed. The social benefits of providing alternative employment for workers currently engaged in peat harvesting would be substantial.

The present fuel payment system whereby the generating station pays a low price for peat and recoups carbon credits for peat combustion from the PSO levy provides no incentive for the generator to change from the use of peat and does not provide an economic price for the energy crop producer. The price currently paid for peat (€3.50/GJ, or about €42 per tonne of biomass) would not cover the cost of producing energy crops. If the payment system were modified to allow the saving in carbon credits to the electricity producer to be used to top up the raw material price paid to the grower, and an establishment grant scheme and VAT relief on planting were available to the producer, some progress towards the Green Paper target could be expected.

Small grid-connected CHP plants based on either combustion or digestion of biomass have developed in other countries where higher prices are available for renewable electricity. Prices of at least €0.12/kWh for a number of pilot projects are needed to get some development under way in this area.

Small-scale on-site off-grid electricity generation from biomass in CHP plants should also be brought into consideration. New micro-turbine based technologies are beginning to emerge that may prove economic in applications where suitably matched power and heat loads are available for a high number of working hours per year. Grant aid will be needed to get a number of pioneering projects off the ground.

Biofuel quality: Just as with liquid biofuels, an effective and stringent solid fuel quality control and monitoring system is required for chipped and pelleted materials to build consumer confidence in a fledgling industry. For wood chips, the most important quality factors are likely to be moisture content, chip size and contaminants. For pellets, moisture content, durability, calorific value and ash content are the main concerns. Facilities for the measurement of these properties are being put in place in Oak Park.

Land use and biofuels

Taking account of all the foregoing, what should be our targets for the development of the various biofuel sectors? In the short term, the first target should be the achievement of the 2% substitution target (Table 2). The 5.75% target would require 150-250,000 ha of tillage land. If we were to ignore this and aim instead at 25% of the commercial heat market and 10% of the residential oil/gas market, we would substitute the same amount of fossil energy (450 ktoe). This would require about 45,000 ha of land that is currently in grassland or tillage (Table 2). To make a start on the supply of biomass to power stations, the Green Paper target of 30% substitution of peat would require about 600,000 tonnes of biomass - 60,000 ha if all produced by energy crops (Table 2).

The achievement of these targets would require that the produce of an area of at most 180,000 ha be devoted to fuel crops. Given that a considerable amount of biofuels will be imported and some of the demand will be met from residue materials, the actual area required would be less than this. But the effect on land use and farming would be significant but not traumatic.

Profitability for biofuel growers and processors remains a problem. The promised increase in the carbon premium for biofuel crops on non-setaside land up to €125/ha is welcome. To broaden farmer interest in energy crop production, one further issue will have to be addressed. Under the current REPS rules, farmers who grow energy crops lose their REPS payments. This anomaly is unjustifiable and significantly reduces the pool of farmers who might consider growing energy crops. A total of over 50,000 farmers with 1.85 million ha of land in the REPS scheme are currently excluded on this basis.

Table 2: Energy and land needed for various biofuel substitution targets

Substitution	Energy demand (ktoe*)	Land needed (ha)
Total national energy demand	• ~16,000	• ~5 million
2% of transport fuel (arable)	• ~80	• ~75,000
5.75% of transport fuel (arable)	• ~265	• ~150-250,000
25% of commercial oil/gas/coal	• ~250	• ~25,000
10% of residential oil/coal/gas	• ~200	• ~20,000
30% of peat in power stations	• ~600	• ~60,000

**1 ktoe = 1000 tonnes of oil equivalent*

Longer-term development is difficult to forecast at this stage. Much will depend on the rate of development of second-generation biofuel technologies, especially those aimed at converting cellulosic materials to liquid biofuel. But if we establish the feedstock production and supply chains to achieve the short-term targets, there should be little difficulty in expanding or adapting to meet future targets as opportunities develop. In the meantime, useful studies could be carried out of the feedstock quality requirements of the second-generation technologies, the economies of scale, and the logistics and environmental impacts of growing and assembling the volume of feedstock needed for viability.

CONCLUSIONS

A transfer of some land from food/feed production into energy crops along with the use of forest and crop residues as fuels can bring substantial improvements in energy supply security and greenhouse gas balance; a reduction of food/feed production should also help to stabilise prices for these products. So the Green Paper focus on increasing the use of biomass as fuel is to be welcomed.

Biofuel industries can develop only if they are profitable for raw material supplier and processor, and attractive to investors. At present there is still an over-riding problem that the profitability of producing and processing biofuel crops remains very low. If the industry is to develop to a significant scale, ways of improving profitability must be found. Some of these are suitable subjects for R&D, e.g. finding profitable fuel uses for rape straw, lower-cost perennial crop establishment systems, feasibility of pelleting non-wood materials, use of energy crop sites for effluent disposal etc. Research Stimulus funding in these areas is proving valuable, and should be continued and expanded. But there are also a number of policy and incentive issues that need to be addressed:

- A change from excise relief on transport biofuels to substitution obligations on oil companies should be introduced gradually as the biofuel production industry matures.

- To the maximum possible extent, support measures should favour projects involving short transport distances for raw material and finished product. This should boost home production and reduce the net exchequer cost of the support measures.

- The large investment and long lead-in time required to change land use patterns and establish biofuel processing facilities needs to be recognised. The present MOTR scheme has a life of only five years. A longer-term guarantee of support will be needed to secure commitment from biofuel crop producers and investors in process plant.

- The promised establishment grant scheme along with VAT exemption on planting materials to offset the high initial cost of perennial energy crops such as willow and miscanthus is needed. The area supported by the grant scheme needs to be big enough to be of national significance.

- To stimulate the development of solid biofuel supply chains, support for their establishment similar to the DEFRA Bio-energy Infrastructure Scheme should be introduced.

- For power station use, the payment system for fuel needs to be modified to allow the reduced need for carbon credits when biomass is burned instead of fossil fuel to be passed to the raw material producer.

- The anomaly of excluding REPS participants from energy crop production needs to be eliminated.

- Pilot projects are needed to promote technologies that are being adopted in other countries but have not yet got off the ground here, e.g. biogas from crops and wastes and small-scale CHP and electricity generation. To get such projects moving, an increased price for bio-electricity pilot projects (at least €0.12 per kWh) is needed.

- Studies are needed on the logistical and environmental aspects of energy crop production that is concentrated near power stations or 2^{nd} generation liquid biofuel technologies.

- Looking further ahead, the feedstock quality requirements and required scale of the emerging lignocellulose-to-biofuel technologies should be investigated.

- Finally, if the momentum generated by initiatives such as the MOTR, BioHeat and Greener Homes scheme is to be sustained, and if home production of biofuels is to be optimised, decision-making time-scales need to be accelerated and structures streamlined to allow this to happen. Short delays in processing the MOTR and establishment grant schemes can set back planting decisions by a year or more. Any capital grant aid for pellet production facilities needs to be processed quickly before imports become entrenched in the market. A more coherent, responsive structure for the speedy handling of all these issues is needed.

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Can we Reduce Costs and Increase Profits?

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SUMMARY

The production of cereals has become a well-defined operation with predetermined levels of inputs applied in an easily managed system. These production systems may not optimize profit however as they were developed in times when grain prices were high and yields were increasing. Today, the correct balance between cost reduction and exploitation of our climates yield potential must be strived for. The Oak Park systems trial was established to determine the effect of the level of inputs on grain yield and profit margin in continuous cereal and rotation systems. Where high and low input rates were evaluated over a long period, the use of high level of inputs usually resulted in higher yields, but the impact on profit was dependent on the level of yield increase and the crop. With winter wheat the low input system returned greater profits in nine of the eleven trial years. Profit was similar with both high and low input systems in winter barley, while both winter oats and spring barley crops generated greater profits where higher levels of inputs were used. The studies indicated that the chosen nitrogen levels had most impact on yield and profit with spring barley and that where low nitrogen levels were used, low fungicide levels should also be used. While results from the use of decision support systems to determine input levels were mixed, the variability in response with winter wheat indicated the potential for decision support systems, and the need for their further development.

INTRODUCTION

The production of cereal crops has become a well defined practice where levels of crop inputs such as seed, fertilisers, herbicides and fungicides are pre-determined almost entirely by crop type and sowing date. Crop production research since the 1980s coupled with practical farm experience forms the basis for this approach. This approach is underpinned by single factor research trials, where the effect of one factor (e.g. fungicide) on crop performance is measured. The primary measurement in these trials is usually grain yield with a lesser emphasis on financial return. The effect that different inputs may have on each other, i.e. interaction, has been studied to a much lesser degree.

The production systems used on farms typically allow the full yield potential of crops to be achieved, within the constraints of site and season. Relatively high rates of inputs are usually used. This 'insurance' type approach to input application has certain benefits.

- Adequate inputs are applied to ensure that where a crop is challenged by weeds, disease, or access to nutrients, yield can still be maximised.
- No single input will be found limiting given the vagaries of growing seasons.
- Management is more straightforward and work planning is easier implement.
- Perceived risk is reduced.

There are disadvantages however

- For many of the inputs that we apply, this approach can result in levels of individual input being applied which do not give an economic response.
- In certain years, factors outside of our control may limit yield thereby rendering high levels of inputs wasteful and uneconomic.

The yield-driven, high-input approach was developed in times when grain prices were high compared to production prices and when developments in crop breeding and production systems were being adopted at farm level, giving substantial increases in yields. Today the economic and production climates are different. While current grain prices are strong, overall production margins will remain tight with greater price volatility becoming a feature, rather than high and stable prices. Developments in cereal production will continue, however the yield gains are likely to be more modest than those achieved in the past, and research emphasis is shifting towards robust sustainable production systems.

Low cost and optimised costs

This changed economic and production background demands that we question the use of high input systems. The fixed-rate, high-input approach must be challenged to ensure that cereal production remains profitable and competitive. While cost reduction can be a valid strategy targeted at improving competitiveness – it can not be an end in itself. The aim must be to get the correct balance between costs and output, i.e. cost optimisation. This objective can be difficult to achieve in practice, largely due to differences in growing seasons.

Very low input cereal production would not allow us to benefit from our natural advantages (unless in an organic system). The use of relatively high levels of inputs, particularly fungicides, to protect crops from wet weather diseases, has allowed us to consistently produce the highest cereal yields in Europe.

System trials

To research low-cost or optimised cost strategies, a number of approaches can be taken:

1. *Single factor trials:* The response from the application of individual inputs can be examined in isolation. E.g. we can individually look at the response to fungicide type and rate, Nitrogen, seedrate etc. This component work is the mainstay of crop production research.
2. *Multi factor trials:* The response to a combination of factors can be studied E.g. the effect of fungicide on different varieties. This yields information about the interaction of different components of a production system.
3. *Systems trials:* Complete production systems can be evaluated. In this approach, systems of production (e.g. low input systems, high input systems etc) can be compared.

There are advantages and disadvantages to each of these approaches. The single factor approach, while often giving the clearest results, fails to capture possible interactions between different inputs. The second option can pick up these interactions, but experimentally can be very complex if combinations of different levels of inputs are to be evaluated. The systems approach does not attempt to measure the interactions between the different inputs. It relies on the sensible choice of input levels which are characteristic of the system chosen. Only the complete systems can be validly compared. While this makes the trial design manageable, the downside is that we may not know what components contribute to a particular performance result.

From a research perspective, no single approach is perfect. In practice we use a combination of the three approaches. The input levels used in the system trials are frequently determined by component trials at Oak Park.

Systems trials and cost reduction

If a research objective is to reduce or optimise production costs, then by working with more than one input for example gives us a greater opportunity to reduce costs. There may also be a synergistic benefit in tackling more than one input. In its simplest form, if reducing the rate of one input lowers the yield potential, then it may be possible to reduce other inputs without further negative impact on yield. In addition there may be further biological reasons for getting a synergistic benefit from reducing more than one input. If a low seeding rate is used with winter wheat for example coupled with a lower nitrogen rate, then the widely spaced and not-too-lush plants may be less susceptible to fungal disease spread, thereby reducing the need for fungicide.

TEAGASC CEREAL SYSTEMS TRIALS

The cereal systems trial, which is mainly carried out at Knockbeg but with some elements evaluated in Kildalton, has two main objectives:

- To assess the effect of rotations on crop production and profitability.
- To assess the effect of input level on crop performance and profitability.

The effect of rotations has been covered comprehensibly in a previous paper (Forristal et al 2005). In summary this work found that the incorporation of break crops did benefit the subsequent cereal crop with higher yields and more profitable margins achieved. However when the profitability of all the crops in the rotation was taken into account, there was little difference between continuous wheat and either of the two rotation types evaluated at the Knockbeg site. This paper will focus on the effect of input levels.

Experimental design and treatments

Three rotations and up to four input levels are being evaluated in the systems work. The rotations include a five-course break-crop rotation which includes: Beans; Winter Wheat, Spring Barley, Oilseed Rape; and Winter Barley. A three-course cereal rotation which includes oats as a break for take-all includes: Winter Wheat; Winter Barley and Winter Oats. The third growing option: monoculture, is evaluated by growing continuous winter wheat and continuous spring barley.

While just two input levels were used originally, the experimental layout used since 2004 allows four input levels to be assessed on each crop grown in each rotation. Four input options are used in Winter Wheat and Spring Barley crops. Two levels of inputs – 'High' and 'Low' are used on the other crops. The input levels used include:

- *High*: Commercial rates of all inputs including Teagasc recommended rates of fertilisers and typically about 80% of plant protection product label rates.
- *Low:* Approximately 80% of the recommended N rates and 50% of the plant protection product rates used in 'High'.
- *Decision-Based High (DB High):* A strategy where knowledge about the crop and growing conditions is used to optimise input application to achieve high yields and optimum returns, using the 'High' treatment as a base. This strategy was only used on winter wheat where the DESSAC decision support system was used to determine fungicide application levels.
- *Decision-Based Low (DB Low):* A strategy where knowledge about the crop and growing conditions is used to optimise inputs in a low input approach based on the 'Low' treatment. This treatment is also only used on winter wheat where the 'Septoria timer' is used to influence the fungicide programme.

- *High-Nitrogen Low-Fungicide (HN LF):* A treatment coupling the Nitrogen levels of the 'High' strategy with the fungicide rates of the 'Low'. It is only used on spring barley to determine which factor influences the response in a two-factor design.
- *Low-Nitrogen High-Fungicide (LN HF):* A treatment utilising the Nitrogen levels of the 'Low' strategy with the fungicide rates of the 'High'. Only used on spring barley.

The basic 'High' and 'Low' input levels have been applied to crops for 11 seasons. Varieties and the plant protection products used have changed over this period to reflect new developments in these areas. In 2004 the decision-based and additional nitrogen/fungicide combinations were added for winter wheat and spring barley respectively. Phosphorus and potassium application levels are based on soil analysis where the low input strategies are used, while a maintenance dressing of P and K is always used with the high input strategies. In practice, no P was necessary on the 'Low' plots until 2005 when maintenance dressings recommenced. For most years of the trial, the variety and sowing date used for winter wheat was the same for all input treatments. For the 2004/2005 and subsequent seasons it was decided to use a later sowing date and more disease resistant variety in the 'Low' strategies to reduce disease and weed pressure. A full description of the input levels used in 2006 on winter wheat and spring barley is given in Appendix 1.

The trial has been carried out for eleven seasons at Knockbeg. To assess and validate the input levels at a more disease prone location, a site incorporating the continuous wheat and continuous barley elements was established in Kildalton. This site has generated two years data to date.

The performance of the treatment strategies is assessed in many ways. Crop and soil nutrient levels, disease assessments, all yield components and grain quality measurements are recorded in all cases. Financial performance is assessed using the cost of the various inputs. For the purposes of this paper, only the two main performance criteria: grain yield and production margin are examined.

Costing analysis

Production costs are estimated by using product prices typical of those available to a 100 ha producer of cereals. While these are calculated each year, to deal with product inflation, the prices used in this paper, when analysing performance over eleven seasons, are those applicable for 2006. Similarly grain prices used in these calculations are the mean of the 2005 and 2006 harvest prices corrected to 15% moisture content. The exception to this approach is when the decision-based and alternative nitrogen and fungicide combinations of the last 3 years are assessed – in this case the actual prices appropriate for the three years are used. In all cases machinery costs are included at contractor charge level. Cost samples are given in Appendix 2. While the costs used will differ from those achieved on some farms, the approach allows a valid and accurate comparisons of the treatments.

RESULTS

High vs Low inputs

The trends and levels of grain yield for the cereal crops grown for 11 seasons at Knockbeg are illustrated in Figures 1, 3, 5 and 7. Each graph includes data points and trend lines for yields of the ‘High’ and ‘Low’ treatments with each crop. In this series of graphs the yield figures are the combined figures for all rotations where the crop type is grown in rotation. E.g. the wheat yields in Figure 1 are the average values for wheats grown in monoculture and the two rotation types at each input level. The associated crop production margin trends are illustrated in Figs 2, 4, 6 and 8. These margins are calculated using today’s costs and returns and exclude any area aid or single farm payment.

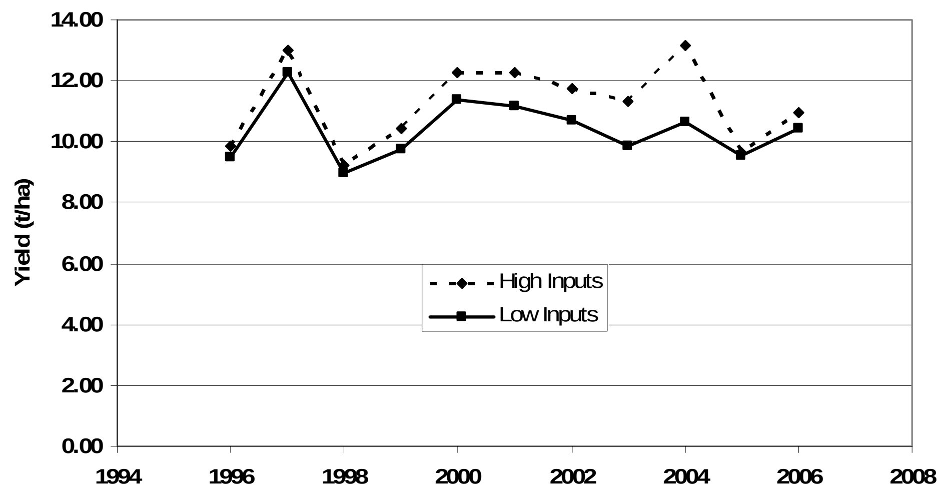

Fig. 1: Winter wheat yield trends with ‘High’ and ‘Low’ input levels: Knockbeg.

Winter wheat: Wheat yields at both input levels varied considerably over time with yields varying from 9.2 to 13.2 t/ha for ‘High’ input levels and from 9.0 to 12.3 t/ha for ‘Low’ inputs. Variations in growing seasons influence disease development and yield potential. The average difference in yield between the two input levels was 0.87 t/ha in favour of the high input system (8.4%) but this varied from no yield difference (1998, 2005) to a 2.5t/ha (23%) difference in 2004.

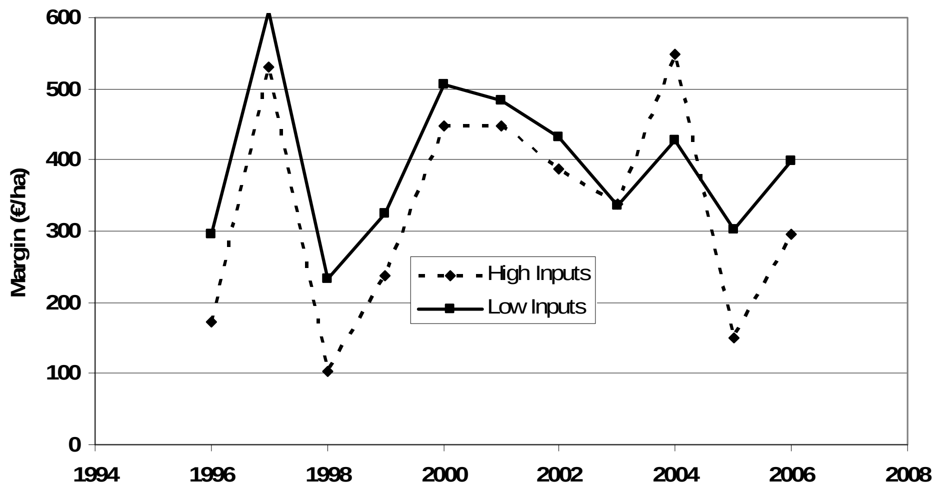

Fig. 2: Winter wheat margin trends with 'High' and 'Low' input levels: Knockbeg.

The true measure of the performance of these systems though is their impact on production margins (Fig 2). On average the 'Low' input system has a production cost of €161/ha less than the 'High' system which amounts to a saving of the equivalent of 1.4t/ha in grain yield. Over the 11 years of the trial, the use of 'Low' input levels resulted in an average increased margin of €62 / ha. With low inputs the cost saving made was worth more than the yield foregone. The dramatic variation in margins across years is a feature of low margin production systems. In 9 out of the 11 years, the low input system generated more income. In only one year when winter wheat yield potential was at it's highest (2004), did the high input system give a better return. Seasons which had a relatively low yield potential greatly favoured the low input approach with margin differences approaching €150/ha. It is ironic that the high input system which is considered an insurance based approach, results in a lower but also more variable production margin. Low cost approaches to winter wheat production offer considerable potential.

Winter Barley: The contribution of the 'High' input system to yield in winter barley was more consistent and averaged 1.1 t/ha over all years representing a 14% increase in yield (Fig 3). The difference in yield between the two input levels varied from 0.8t/ha (12%) to 1.6t/ha (20%).

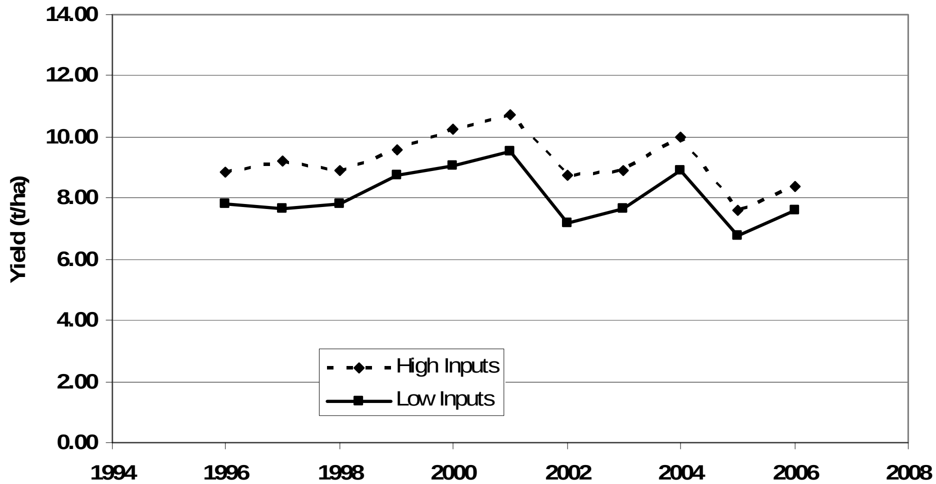

Fig. 3: Winter barley yield trends with 'High' and 'Low' input levels: Knockbeg

When production costs are included, and all 11 years are considered, input level had no effect on margin (Fig 4). With low inputs the cost savings made are cancelled by the reduction in yield. While there are some differences in margin in individual years, they were small. While the low input system evaluated showed little scope for improving margin in winter barley, there is equally no yield penalty from using a low input approach.

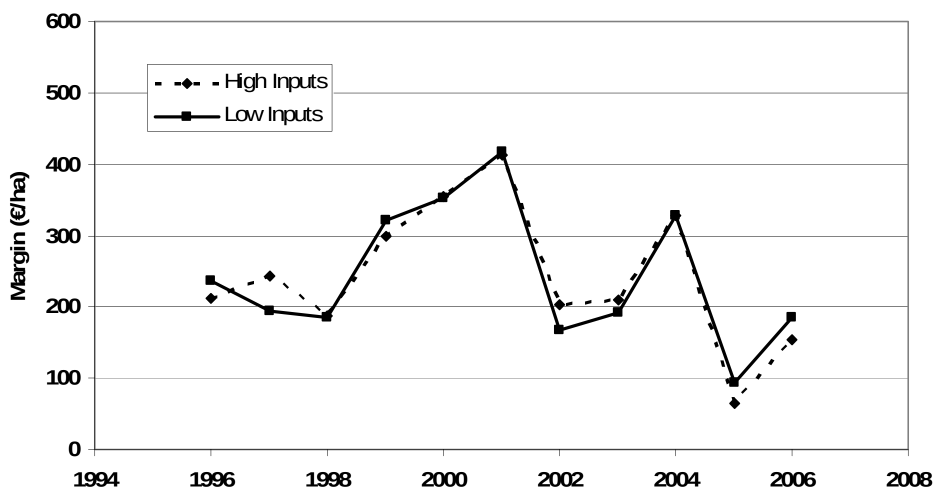

Fig. 4: Winter barley margin trends with 'High' and 'Low' input levels: Knockbeg

Winter Oats: The yield of the winter oat crop was also increased where high inputs were used (Fig 5). Overall a yield increase of 1t/ha (11%) was recorded with a relatively consistent increase in most years, except for 1998 when the crop lodged.

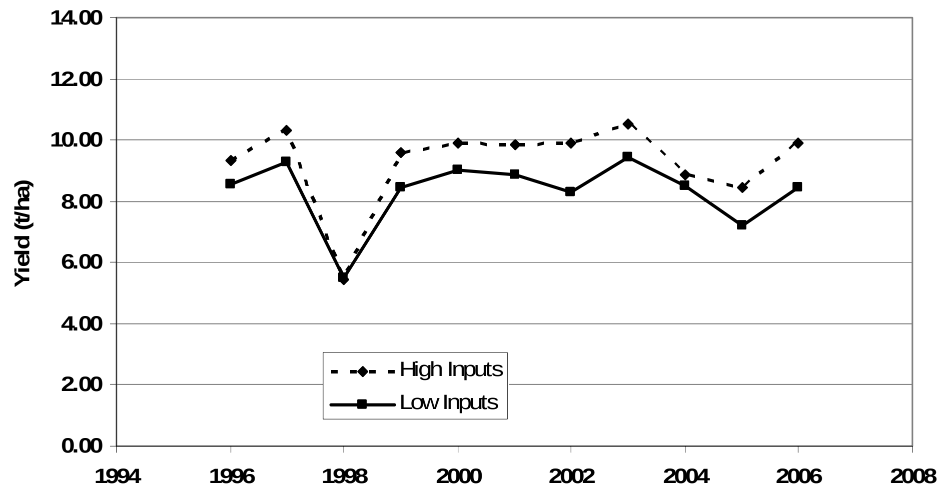

Fig. 5: Winter oats yield trends with 'High' and 'Low' input levels: Knockbeg

While this yield difference is not that large, it does result in an average margin increase of €46/ha for the high input strategy (Fig 6). There is little difference in costs between the two systems as the 'High' input approach chosen for oats in this trial uses a quite modest level of inputs. Note the negative margin recorded for 1998 using today's prices.

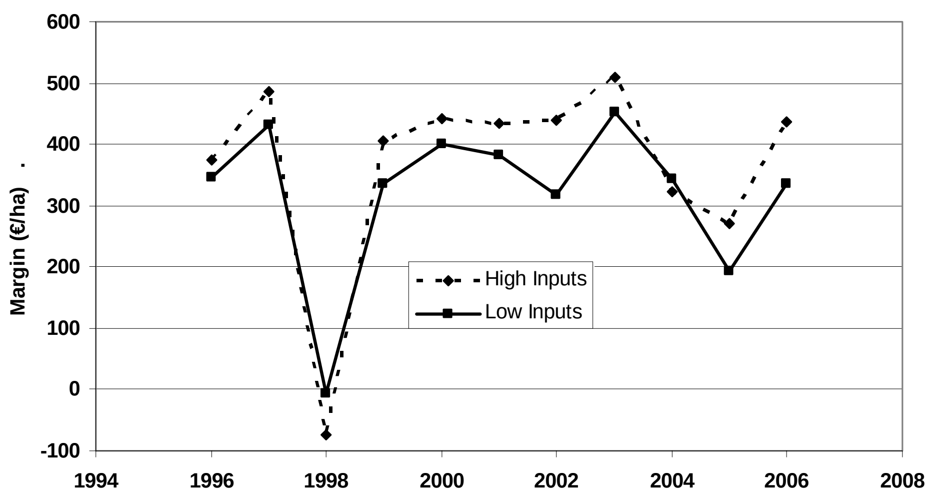

Fig. 6: Winter oats margin trends with 'High' and 'Low' input levels: Knockbeg

Spring Barley: Spring barley had the greatest difference in yield between the two input systems when expressed in percentage terms. The average yield difference over the 11 years was 1.2 t/ha which represents 18% of the low input yield level (Fig 7). While there was some variation from year to year, the trend was similar in all years.

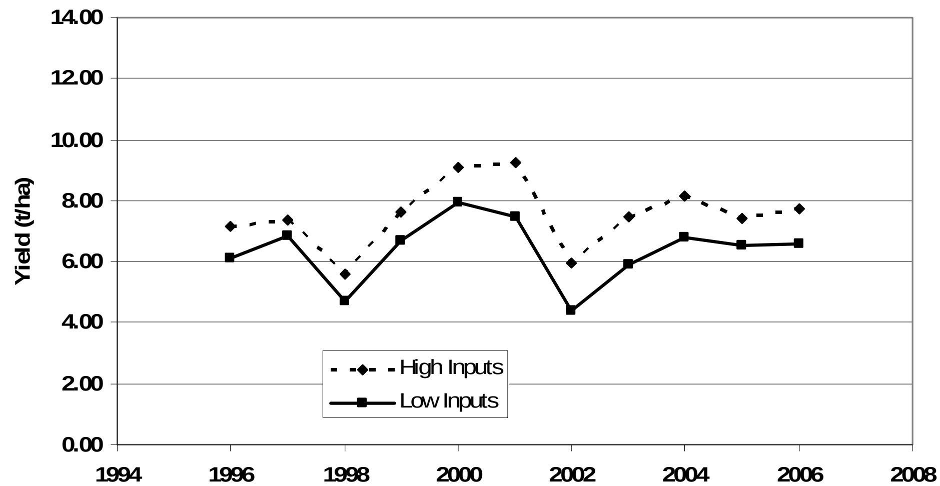

Fig. 7: Spring barley yield trends with 'High' and 'Low' input levels: Knockbeg

Production cost differences between the low and high input strategies used on spring barley was €81/ha using today's costs. A yield difference of just 0.7t/ha would pay for the higher input levels. Overall the high input strategy results in a margin improvement of €55/ha (Fig 8). This difference cannot be ignored in the context of the low margins achieved with spring barley. In 2002 when yields were low, at today's prices, the low input approach would have resulted in a negative margin, while higher input levels would have prevented a negative margin being generated. These results are important for cereal growers that participate in the REP scheme where allowed nitrogen levels are similar to the low-input treatment here. The cause of this difference is discussed in a later section.

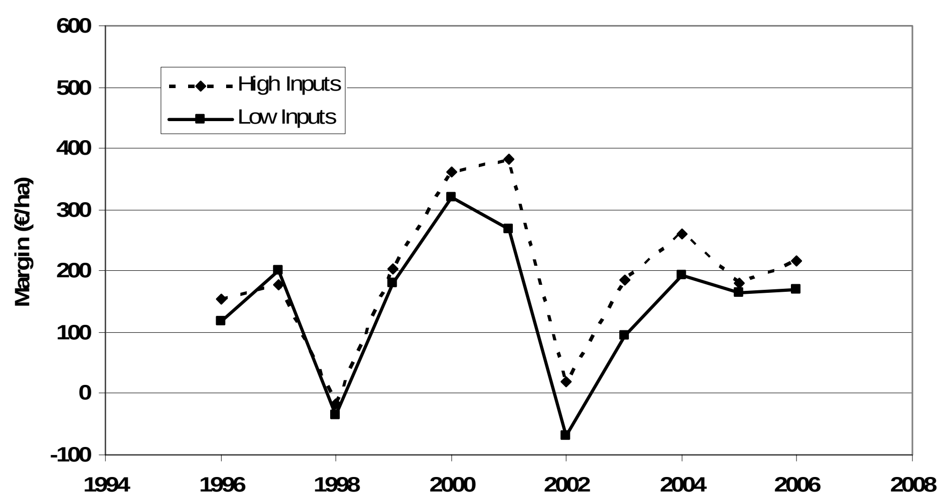

Fig. 8: Spring Barley margin trends with 'High' and 'Low' input levels: Knockbeg

Input levels and rotations

The Knockbeg trial allows the interaction between rotation type and input level to be assessed. Winter wheat and winter barley are both grown in potentially beneficial parts of the two rotations. Cereals grown after break crops may benefit less from higher levels of inputs than cereals grown in monoculture. The average (11 year) yields for winter wheat and winter barley grown in rotations or in monoculture (or a non-beneficial part of the rotation) are given in Figure 9 with the associated production margins in Figure 10. While the trends in this data would indicate that crops grown in beneficial positions of rotations benefit more from a low-input approach, the differences may not be significant. With wheat for example a low-input approach boosts margins by €72/ha compared to €42 for continuous wheat. Similarly low-input winter barley grown after oilseed rape had an increased margin of €16 /ha, whereas the low-input strategy applied to winter barley grown after winter wheat in a cereal rotation showed a reduced margin of €15/ha (difference of €31/ha).

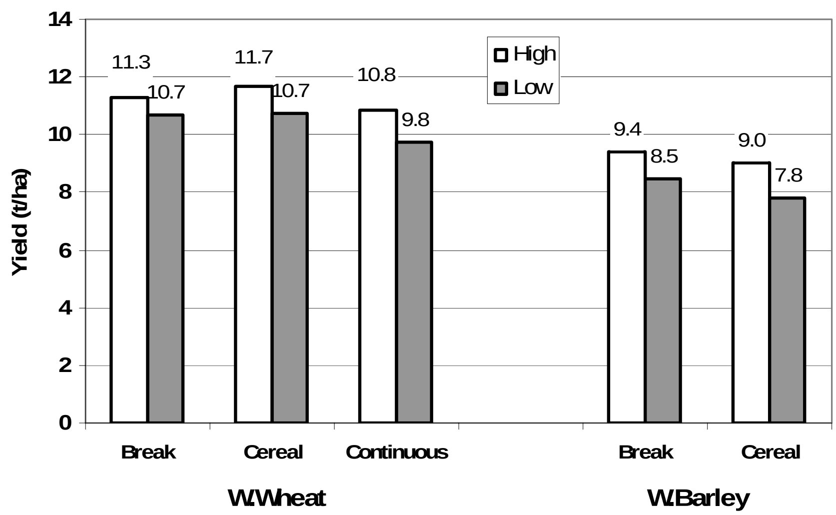

Fig. 9: The effect of rotation on wheat and barley yields with different input levels

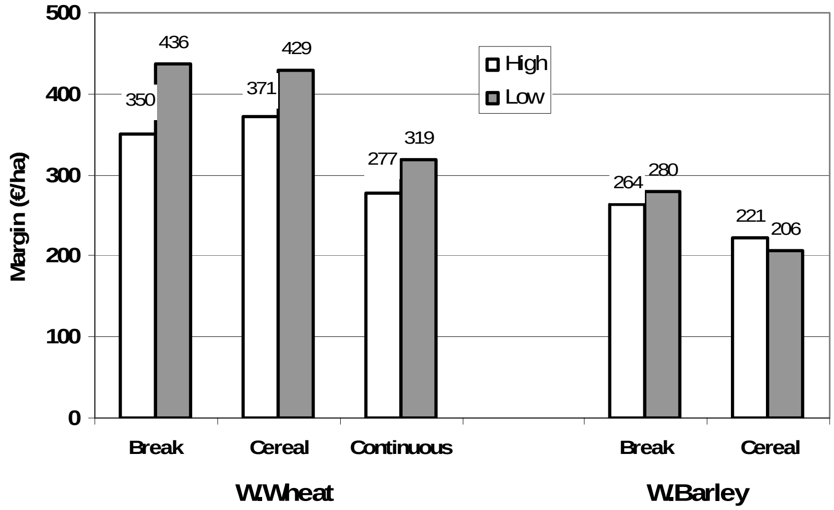

Fig. 10: The effect of rotation on wheat and barley margins with different input levels

Decision-based strategies

Additional decision-based input strategies for winter wheat were added at the Knockbeg site for the 2004 season. These were also incorporated in the Kildalton site for which we can report two years data (2005 and 2006). The yields and margins associated with these input strategies are illustrated in Figs 11-14. Note the actual costs used in the margins reported here differ from the average costs used in the analysis of the full 11 years data and consequently are not directly comparable. In 2004, the decision based strategies resulted in yield reduction and margin reduction compared to the fixed approaches at Knockbeg (Fig. 11 and 13). The DESSAC system was allowed select an old fungicide technology product which restricted yield potential in the DB-High treatment, while grass weed competition and subsequent expensive late-control measures reduced yields and margins in the DB-Low treatment. In 2005, the decision-based treated plots yielded similarly to the fixed-rate plots resulting in similar margins. There was a tendency for margins to be improved by the decision based strategies in 2006 as yields were maintained and costs reduced.

While the overall benefits from decision-based systems in this trial are negligible to date, the results of the last two years and, particularly the performance of decision support systems in other trials at Oak Park (Burke and Dunne, In-Press), would indicate that they have potential in system-based approaches to crop production. Our long-term wheat results (Fig 1 and 2) which showed that matching input strategy to yield potential could result in substantial margin boosts, also indicates the scope for decision-support type systems.

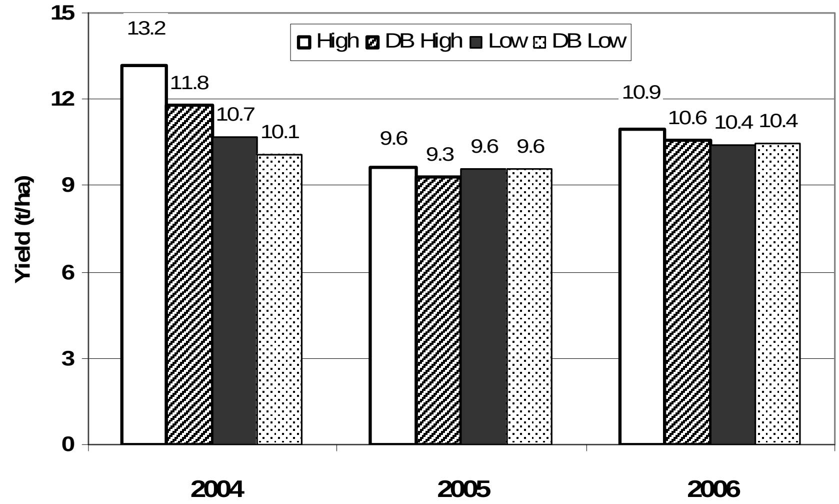

Fig. 11: Winter wheat yield with standard and decision-based strategies at Knockbeg.

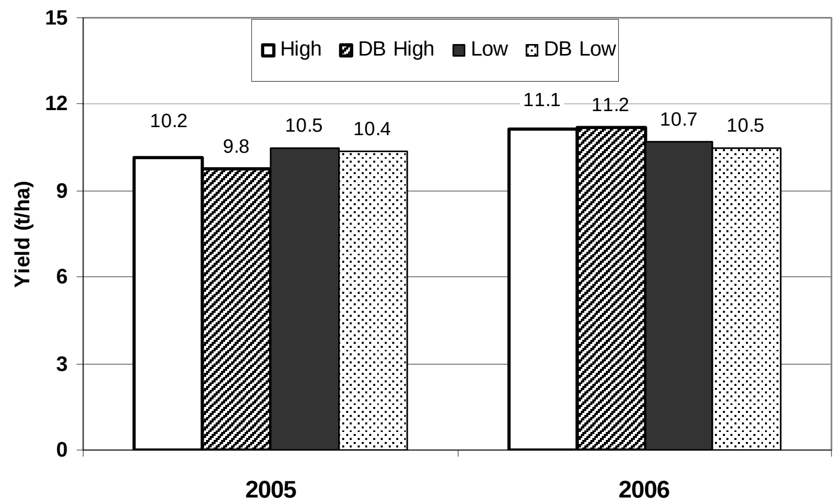

Fig. 12: Winter wheat yield with standard and decision-based strategies at Kildalton.

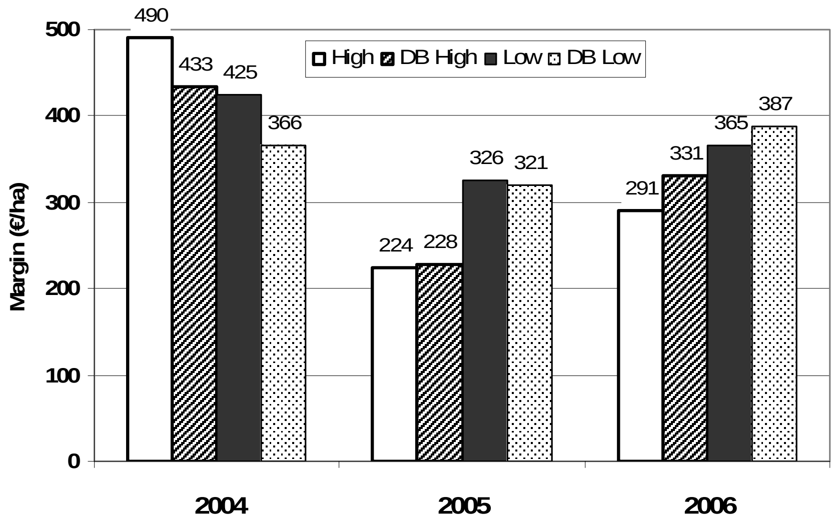

Fig. 13: Winter wheat margin with standard and decision-based strategies at Knockbeg

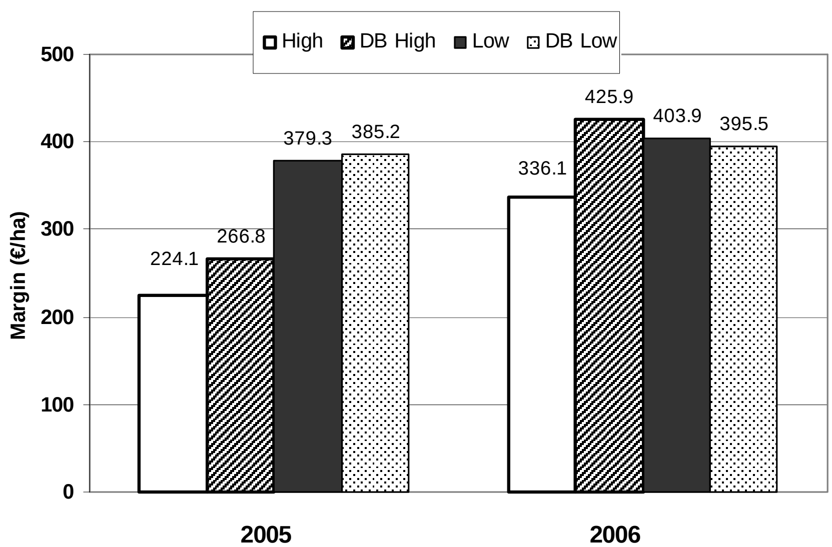

Fig. 14: Winter wheat margin with standard and decision-based strategies at Kildalton

Spring barley nitrogen and fungicide rates

The relatively poor performance of the 'Low' input system with spring barley stimulated further studies to determine the contribution of the fungicide and nitrogen elements of the strategies to these results. Two further treatments HNLF (High Nitrogen, Low Fungicide) and LNHF (Low Nitrogen, Low Fungicide) as described earlier were added in 2004 at Knockbeg (3 years data) and Kildalton (2 years data). The effect of these treatments on yield and margin for all years is summarized in Figs 15 and 16. At Knockbeg, the major factor influencing yield was nitrogen level. Both low (105kg/ha) N level treatments (Low and LNHF) gave reduced yields regardless of fungicide level (Fig 15). Where a high nitrogen level was used, there was some small level of response from using full-rate (High) rather than half-rate (HNLF) fungicide. This response to fungicide just about paid for itself leaving no difference in margins (Fig 16). Where lower Nitrogen levels were used at Knockbeg, there was no benefit in using full-rate fungicide, resulting in a much lower margin where full-rate was used.

Two years data from the more disease prone Kildalton site shows a slightly different picture. Overall there is a significant response to fungicide at the higher nitrogen level resulting in the 'High' treatment giving the best return. At a lower applied Nitrogen level, there was no response to changes in fungicide level resulting in the 'Low' treatment giving a much higher margin than the LNHF treatment. At both sites, at lower N (equivalent to REPs level), the best option was to use half rate fungicide. Also the difference in margin between the basic high and low treatments was less at Kildalton than at Knockbeg.

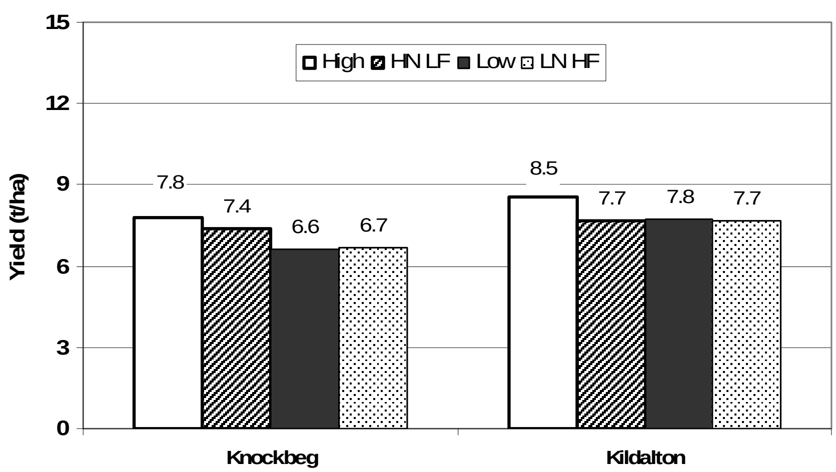

Fig. 15: Spring barley yield with four input levels at Knockbeg (3 yrs) and Kildalton (2 yrs)

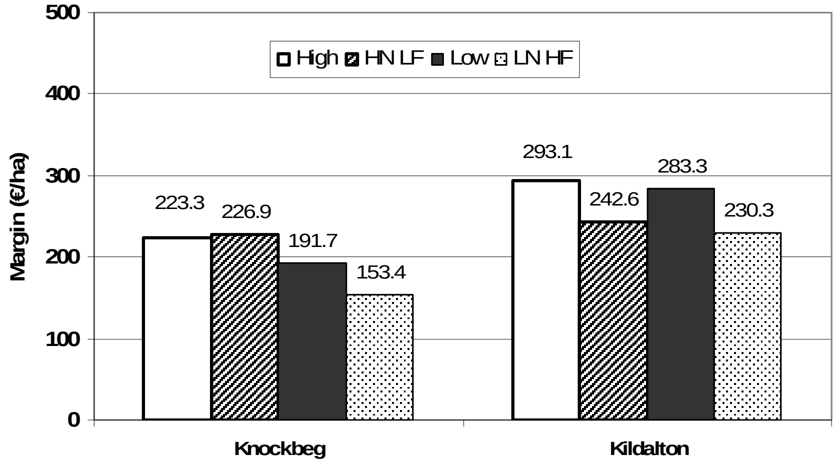

Fig. 16: Spring barley margin with four input levels at Knockbeg (3 yrs) and Kildalton (2 yrs)

CONCLUSIONS

1. Cereal production systems must be selected to optimise profits to ensure competitiveness in difficult and volatile markets.

2. The concept of using easily-managed high-input systems with pre-determined rates of inputs should be challenged to promote the development and application of the most appropriate systems.

3. The lower input systems used in these trials generally reduced yields but the level of yield response and the effect of this response on profit margin was determined by crop and season.

4. With winter wheat, the low input strategy reduced costs by €161/ha and yield by between 0 and 23%. However the low strategy was most profitable with an average annual margin increase of €62/ ha.

5. With winter barley the yield response was more consistent, but the level of inputs used in the trial had little effect on crop production margin.

6. Spring barley also responded better to higher input levels which gave an 18% increase in yield resulting in a margin increase of €55/ha. A more detailed study showed that the greater part of this response was attributable to nitrogen levels and where lower nitrogen levels are applied, lower fungicide levels should be used.

7. There was some evidence that the low input approach was more profitable on cereal crops grown in beneficial parts of the rotation.

8. While decision-based input strategies did not perform particularly well in this trial, they did show some potential. Other Oak Park research and the variation in seasonal response to inputs recorded in this trial indicates the potential for targeting inputs to give better returns.

9. Early prediction of yield potential and subsequent tailoring of inputs could bring substantial margin improvements in wheat production.

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Appendix 1: Summary of main inputs on w. wheat and s. barley.

Crop	W.Wheat				S.Barley	
Input Level	High	DB High	Low	DB Low	High	Low
Seed (kg/ha)	112	112	125	125	145	145
N (kg/ha)	225	225	187	187	137	105
Growth Reg. (l/ha)	Meteor: 2.5	CCC: 2.25	Meteor: 2.5	Meteor: 2.25		
Herbicide (l/ha)	Cougar: 1.5	Trump: 2.4 IPU: 2	Cougar: 0.8	Cougar: 1.2 IPU: 1	Calibre: 30 Duplos: 1.3	Calibre: 15 Duplos: 0.6
Fungicide T1 (l/ha)	Proline: 0.8 Bravo: 1.0	Proline: 0.8 Bravo: 1.0	Proline: 0.4 Bravo: 0.5	Eyetak: 0.8 Bravo: 1.5	Stereo: 1.0 Corbel: 0.5	Stereo: 0.5 Corbel: 0.25
Fungicide T2 (l/ha)	Venture: 1.5 Bravo: 1.0	Prosaro: 0.6	Venture 0.75 Bravo 0.5	Venture 0.75 Bravo 0.5	Fandango: 1.2 Bravo: 1.0	Fandango: 0.6 Bravo: 0.5
Fungicide T3 (l/ha)	Folicur: 0.8 Amistar: 0.5	Fandango: 0.75	Folicur: 0.4 Amistar: 0.3	Folicur: 0.4 Amistar: 0.3		

Appendix 2: Costings used to compare basic treatments over 11 years

Crop	Input level	Rotation	Total costs (€)	Price (€/t 15%)
W. Wheat	High	Break	974	113.69
		Cereal, Contin	993	113.69
	Low	Break	816	113.69
		Cereal, Contin	830	113.69
W. Barley	High	All	824	109.43
	Low	All	707	109.43
W. Oats	High	All	758	115.81
	Low	All	692	115.81
S.Barley	High	All	681	109.43
	Low	All	600	109.43

Fungicide Resistance – an increasing problem

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SUMMARY

Investigations of randomly-selected wheat crops in 2006 showed that strobilurin resistance in *Septoria tritici* was higher than it had been in 2003. This is despite a reduction in selective pressure for resistance due to reduced use of strobilurins for disease control in wheat in recent years.

Septoria populations remained sensitive to the triazoles Opus and Proline; the levels of sensitivity to these two products have not changed since 2003. There were shifts in the sensitivity of septoria to the triazoles Folicur and Caramba between 2004 and 2005 but no further reductions in sensitivity between 2005 and 2006. There is cross-sensitivity between Folicur and Caramba and spraying with either fungicide rapidly selects an insensitive septoria population which in turn reduces the efficacy of both fungicides. Septoria populations with reduced sensitivity to Folicur and Caramba are not less sensitive to Opus and Proline.

A new race of the barley leaf scald pathogen *Rhynchosporium secalis* emerged which caused severe disease on the previously resistant barley cultivar Doyen. Rhynchosporium populations in 2006 had the same levels of sensitivity to triazole and strobilurin fungicides as they had in 2003.

Studies of eyespot in wheat crops showed that the R type (*Tapesia acuformis*) is still the dominant strain and all populations are still predominantly resistant to MBC fungicides. There is also reduced sensitivity to Sportak and Unix.

Because of the occurrence of resistance to strobilurins the triazoles are now the most important group of fungicides that are available to cereal growers. Disease control must be managed in a way that minimises the potential for the build-up of insensitivity to these fungicides in fungal pathogens. Triazole fungicides should be mixed with suitable non cross-resistant partner fungicides such as chlothalonil or boscalid.

INTRODUCTION

Fungicides have been used to control plant diseases for over one hundred and fifty years. There were very few instances of resistance to fungicides until the introduction, over thirty years ago, and subsequent widespread use of systemic fungicides. The older fungicides that predated the systemics had both protectant and broad spectrum activity. They were multi-site inhibitors i.e. they interfered with a number of vital functions controlled by a number of genes in the target fungal cell. In order for resistance to develop to these products a number of specific genetic changes would have to occur at the same time in the target pathogen cell and the probability of this occurring is low. The systemic fungicides are usually directed against specific groups of pathogens. Many are single-site inhibitors i.e. they interfere with a vital function controlled by a single gene in the target pathogen cell. This makes it easy for resistance to develop since a single mutation in this gene can negate the effects of the fungicide.

Single genetic changes usually produce highly resistant strains of pathogens. A resistant strain may initially be present at a very low frequency in a pathogen population. It survives fungicide treatments and builds up rapidly, due to absence of competition from sensitive strains, to become the dominant component of the population and disease control fails. Increasing the rate of fungicide applied will not affect control. Resistant strains of pathogens may be less fit and at a competitive disadvantage compared with sensitive strains. In such cases the level of resistance will decrease rapidly if the fungicide concerned is withdrawn though it is likely to build up rapidly again if unrestricted use of the fungicide resumes. If there is not a fitness penalty resistance levels remain high indefinitely even if the fungicide concerned is no longer used.

Frequently a pathogen develops reduced sensitivity to a fungicide rather than complete resistance. Less sensitive strains of the pathogen are selected gradually through small cumulative changes induced by the fungicide. The effects on disease control are not as dramatic as those from complete resistance resulting from single genetic changes. Initially there may be only a slight decrease in sensitivity with no noticeable reduction of disease control. The continued use of the fungicide concerned leads to the selection of strains that are progressively less sensitive with corresponding reductions in fungicide efficacy. In such cases increasing the rate of fungicide may improve disease control.

Fungicide resistance has been recognised as a factor affecting the control of cereal diseases in Ireland since the 1980s when it became apparent that eyespot was no longer being controlled by MBC fungicides. Subsequent investigations showed that populations of the eyespot fungi (*Tapesia yallundae* and *T. acuformis*) had become predominantly resistant to these fungicides (Cunningham 1990). The field performances of some of the older triazole fungicides against Septoria have decreased over the years and this may be due to decreased sensitivity in populations of this pathogen, but there was no initial baseline data for sensitivity to these fungicides.

Baseline data on the sensitivity of some of the major cereal pathogens to the main groups of fungicides used to control them has been compiled at Oak Park since 2002. The results from each season's sensitivity testing are compared with these baselines and in this way any shifts in the sensitivity of pathogens to the fungicides concerned can be detected.

SEPTORIA DISEASE IN WHEAT

Strobilurin resistance in septoria

Resistance to strobilurin fungicides first emerged in *Septoria tritici* populations in Ireland in 2002 and by early 2003 resistance was found in populations in nearly all crops throughout the main wheat-growing regions of the country, usually at a very high frequency. Since 2003 there has been a dramatic reduction in the use of strobilurins in spray programmes on wheat crops, thus reducing the selective pressure for resistance. However, studies of *S. tritici* populations in fifteen selected crops throughout the wheat-growing regions of the country in 2004, 2005 and 2006 detected high levels of strobilurin resistance (Table 1). Levels of resistance in spring 2006, following four seasons of reduced usage of strobilurins, were even higher than they were in 2003 and 2004. So it appears that strobilurin resistance in septoria is genetically stable, does not carry a fitness penalty and will continue to remain high, even when the selection pressure is reduced.

Table 1: Strobilurin resistance in *Septoria tritici* 2003 – 2006

Year	Range of resistance	Average
2003	0% - 84%	48%
2004	50% - 100%	83%
2005	76% - 100%	96%
2006	86% - 100%	97%

Triazole sensitivity in septoria

Populations of *S. tritici* in 2003 were tested for sesitivity to epoxiconazole (Opus), which was the most widely-used triazole product at that time. In 2004, 2005 and 2006 populations were also tested for sensitivity to the triazole fungicides prothioconazole (Proline), tebuconazole (Folicur) and metconazole (Caramba) as well as to Opus. All isolates were sensitive to all fungicides in 2003 and 2004 and the levels of sensitivity detected then have been used as baselines against which sensitivity studies in subsequent years have been measured. There has been no shift in the sensitivity of *S. tritici* populations to Opus since 2003. All isolates tested up to and including 2006 had levels of sensitivity that were broadly similar to those detected in 2003 (Fig1). Levels of sensitivity to Proline have been similar to those for Opus with no shift in sensitivity between 2004 and 2006. There is evidence that when some triazoles are used extensively pathogens become less sensitive to them over time. Septoria is no more sensitive to the recently-introduced Proline than it is to Opus, which has been in use for many years, and this suggests cross-sensitivity between both of these triazoles.

In 2004 septoria populations were largely more sensitive to Folicur and Caramba, particularly to Caramba, where no isolates grew above 0.12ppm, than they were to Opus and Proline. There was a greater range in the sensitivity of isolates to Folicur. While less than 20% of isolates grew above 0.12ppm tebuconazole there were a few that grew up to 3.3ppm (Fig 2) and no isolates grew at this concentration in the case Opus, Proline or Caramba.

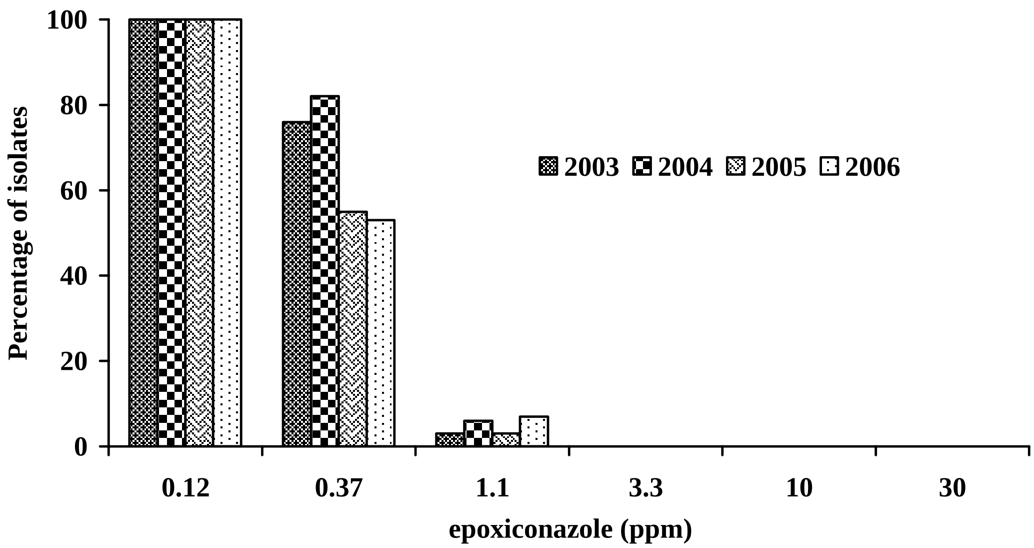

Fig. 1: Sensitivity of *Septoria tritici* isolates to epoxiconazole (Opus) 2003 – 2006

There was a shift in the sensitivity of septoria populations to Folicur from 2004 to 2005 with some isolates growing at concentrations of 10ppm tebuconazole and the proportions of isolates growing at the other concentrations towards the insensitive end of the scale (1.1ppm and 3.3ppm) increasing substantially compared with 2004 (Fig 2). While the proportions of these insensitive isolates of septoria increased in 2006 there was no further shift towards greater insensitivity i.e. no isolates grew above 10ppm tebuconazole which was the highest level of insensitivity detected in 2005. There was also a shift in sensitivity towards Caramba between 2004 and 2005 with isolates that were less sensitive to Folicur being also less sensitive to Caramba.

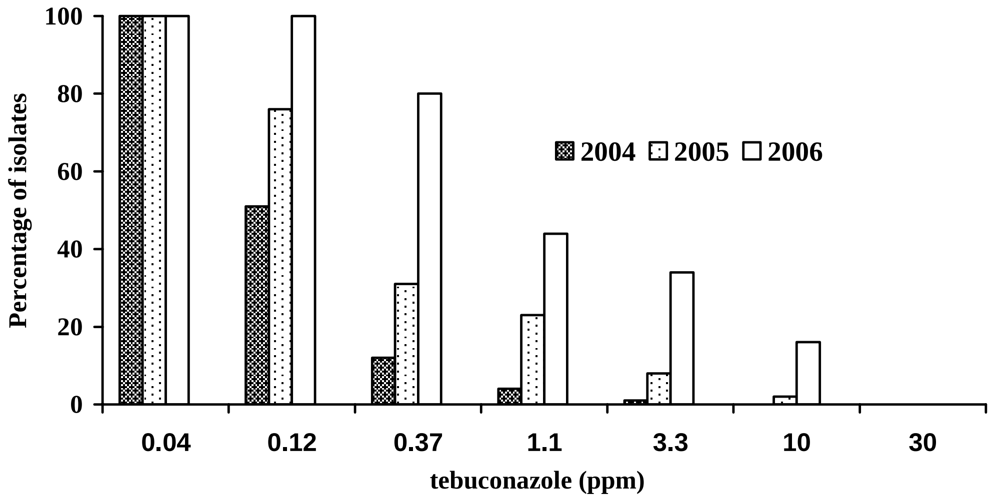

Fig. 2: Sensitivity of *Septoria tritici* isolates to tebuconazole (Folicur) 2004- 2006

Triazole insensitivity selection

In 2005 and 2006 all commercial winter wheat crops were sampled first in February-March, before any fungicides were applied and again in mid-July to determine whether or not the sensitivity of septoria might be affected by the fungicides used in disease control programmes. There were no changes in the sensitivity of septoria populations in any crops to epoxiconazole (Opus) or prothioconazole (Proline) between March and July in either year. This is despite the fact that most crops would have received products containing either or both of these fungicides as components of the various spray programmes used. However Folicur, applied usually at T3, selected septoria populations with reduced sensitivity to that product, and also to Caramba, in both years.

Figure 3 shows an example of a winter wheat crop in 2006 where no Folicur was applied. In this crop there was little change in the sensitivity of septoria to tebuconazole between March and July. Figure 4 shows an example of a crop where Folicur was applied and there was a marked increase in the proportion of insensitive septoria isolates between March and July. In the latter crop also the level of insensitivity to Caramba increased between March and July (Fig 5). This is despite the fact that Caramba had not been used as a component of the spray programme.

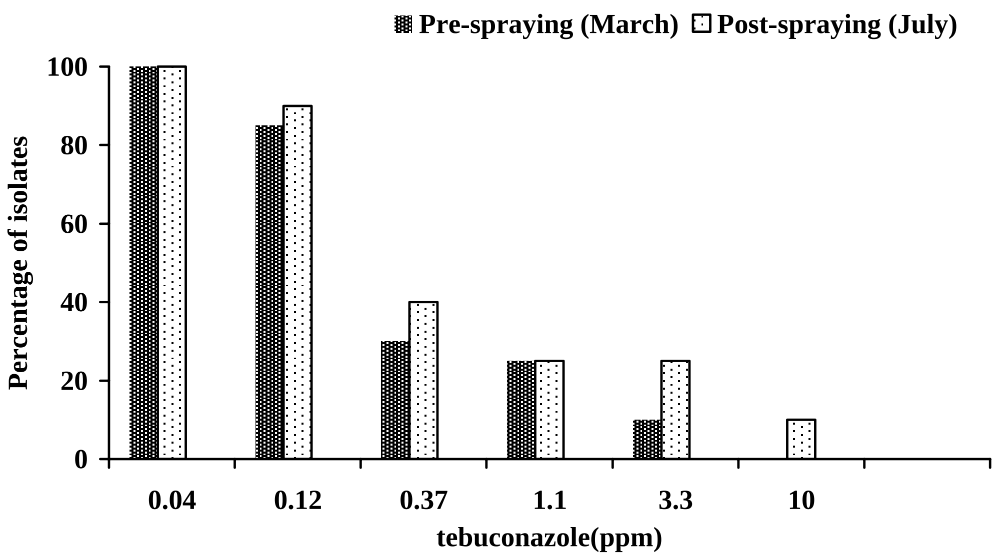

Fig. 3: Sensitivity of *Septoria tritici* isolates to tebuconazole in a commercial wheat crop where Folicur had not been applied

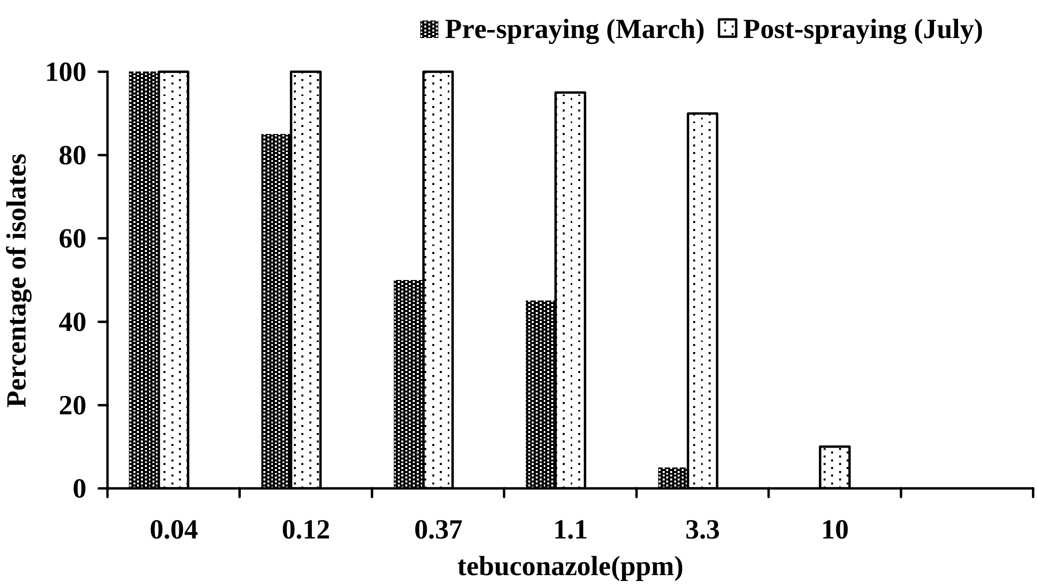

Fig. 4: Sensitivity of *Septoria tritici* isolates to tebuconazole in a commercial wheat crop where Folicur had been applied

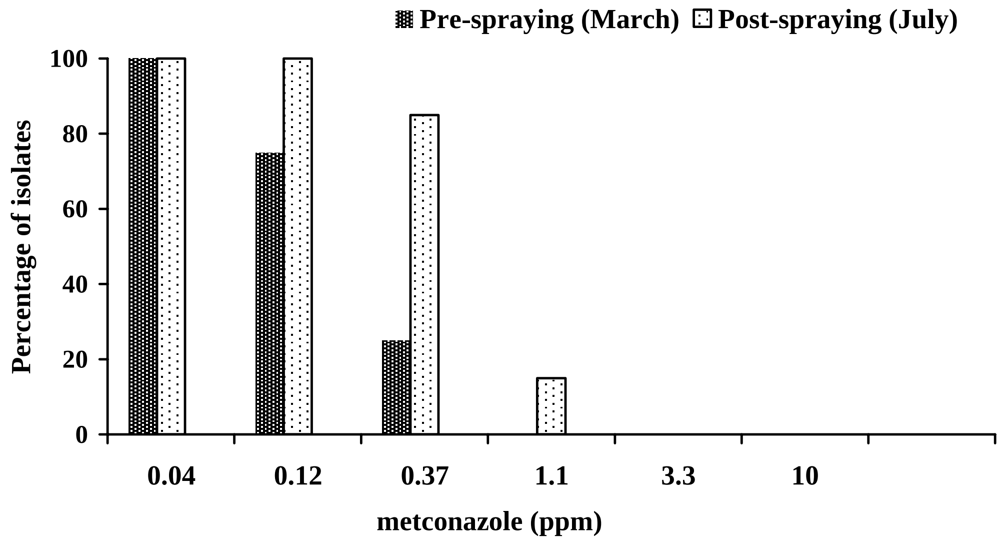

Fig. 5: Sensitivity of *Septoria tritici* isolates to metconazole (Caramba) in a commercial wheat crop where Folicur had been applied

In other investigations on selection for triazole insensitivity, in 2004 and 2005 experimental plots were sprayed three times (T1, T2 and T3) with Opus, Proline, Folicur or Caramba at full, half and a quarter of the recommended rates. The results followed the same pattern in both years. Full or reduced rates of Opus or Proline did not select for insensitivity to either of these fungicides or to Folicur or Caramba. However, full or reduced rates of either Folicur or Caramba selected for insensitivity to both of these fungicides but not to Opus or Proline.

It is likely that reduced rates of fungicides would be less effective in controlling insensitive strains of pathogens than full rates and therefore would be more effective in selecting for insensitivity. However, this is not what has happened in the case of Folicur and Caramba. Whether the same is true for all triazoles is not clear since there have been no shifts in the sensitivity of septoria populations to Opus or Proline during the course of the present investigations.

Clearly, strains have developed in septoria that have reduced sensitivity to Folicur and Caramba and there is cross-sensitivity between these two fungicides. Spraying with Folicur or Caramba rapidly selects an insensitive population of septoria which in turn reduces the efficacy of these products. This has been borne out in Oak Park field trials in 2005 and 2006 where Folicur gave poor disease control compared with previous years.

Fortunately, a reduction in sensitivity to Folicur and Caramba has not affected sensitivity to Opus and Proline. Septoria isolates with reduced sensitivity to the former products are not less sensitive to Opus and Proline. So it appears that, unlike the strobilurins, reduced sensitivity or resistance to some triazole products will not affect all of these products.

The fact that there has been no shift in the sensitivity of septoria to Opus and Proline and that repeated spraying of plots with full or reduced rates of these has not so far selected less sensitive strains is reassuring. However, it cannot be taken for granted that resistance or a shift towards insensitivity will not occur and there must not be a return to the sense of complacency in the use of fungicides that there was before 2003. Disease control must be managed in a way that minimises the potential for the build-up of resistance and some guidelines are discussed later on in this paper.

RHYNCHOSPORIUM IN BARLEY

Leaf scald caused by *Rhynchosporium secalis* is a major disease of winter and spring barley in Ireland. Rhynchosporium overwinters predominantly on stubble debris or volunteer barley from previous crops but it can be carried on seed and transmitted from seed to seedlings (Kay and Owen 1973). Seed transmission is thought to be of minor importance as a source of primary infection though it can be important in long-range dispersal of the pathogen and also in the dispersal of new races. The disease is spread mainly by rain-splash dispersal of spores during the crop growing season. There is no known air-borne stage of the pathogen so resistance to fungicides in *R. secalis* should spread much more slowly than it did in the case of septoria. There are a number of different races of *R. secalis* and these vary in their virulence towards different barley cultivars.

Disease resistant barley cultivars can provide a cost-effective means of control. There are two types of resistance, single gene resistance and multigene resistance. The former gives almost complete disease control and is not affected by disease pressure or environment. However it is race-specific and can be overcome by the emergence of new races of the pathogen. Some highly resistant barley cultivars grown in New Zealand in the 1980s had their resistance eroded by the emergence of new races of rhynchosporium (Cromey, 1987).

Multigene resistance, also referred to as quantitative resistance or field resistance, only gives partial disease control but it is usually more durable than major gene resistance and not likely to be affected by new races. Partial resistance is affected by disease pressure and fungicide treatments are required to control rhynchosporium particularly when disease pressure is high.

A new race of *R. secalis*

The spring barley cultivar Doyen with high resistance to rhynchosporium had been widely grown in Ireland with no reports of severe disease. However in 2006 there were reports of disease epidemics in crops of this cultivar. Leaf samples were obtained from some of these crops in June and rhynchosporium was isolated from them. Cultivars, Lux, Tavern, Wicket and Doyen were inoculated with four rhynchosporium isolates from Doyen, and four isolates from other cultivars including one from 2003. These latter four isolates caused severe disease on Lux, Tavern and Wicket but practically no disease on Doyen. The isolates from Doyen however, caused severe disease on Doyen as well as in the other cultivars. This confirms that Doyen is highly resistant to the rhynchosporium population that is dominant on other cultivars in Ireland. The severe disease on Doyen in 2006 was not due to seasonal disease pressure but to the emergence of a race of *R. secalis* to which the cultivar has no resistance. This race may have been present in Ireland at a very low frequency and built up progressively in Doyen because of lack of competition from other races, or it may have been introduced recently from some external source.

Fungicide sensitivity in rhynchosporium

Previous investigations at Oak Park (2001 to 2003) showed that populations of *R. secalis* were generally sensitive to triazole and strobilurin fungicides with 20 to 30% of isolates resistant to MBC. Rhynchosporium populations were sampled again in 2006 to determine if there had been any shifts in sensitivity since 2003 and there was some concern lest the new race detected on the cultivar Doyen might also be resistant to fungicides. Rhynchosporium isolates collected during summer 2006 were tested for sensitivity to the triazole fungicides prothioconazole (Proline), epoxiconazole (Opus) and flusilazole (Sanction), the strobilurin azoxystrobin (Amistar) and to MBC (benomyl).

Of the triazole products, all isolates were most sensitive to Proline and were more sensitive to Opus than to Sanction (Fig 6). Rhynchosporium from Doyen had the same degree of sensitivity to all three triazole fungicides as that from other sources. Proline had not been included in previous resistance testing but the levels of sensitivity to Opus and Sanction are similar to those detected in 2003. Resistant isolates of *R. secalis* have been found in Scotland that can grow at 30 ppm epoxiconazole but no such isolates have yet been found in Irish populations.

Rhynchosporium from all sources was also sensitive to azoxystrobin with only 28% of isolates able to grow at concentrations up to 0.37% and none able to grow at higher concentrations. There has been no shift in sensitivity since 2003. Some 12% of isolates tested were resistant to MBC which is lower than the 20 to 30% resistance detected from 2001 to 2003.

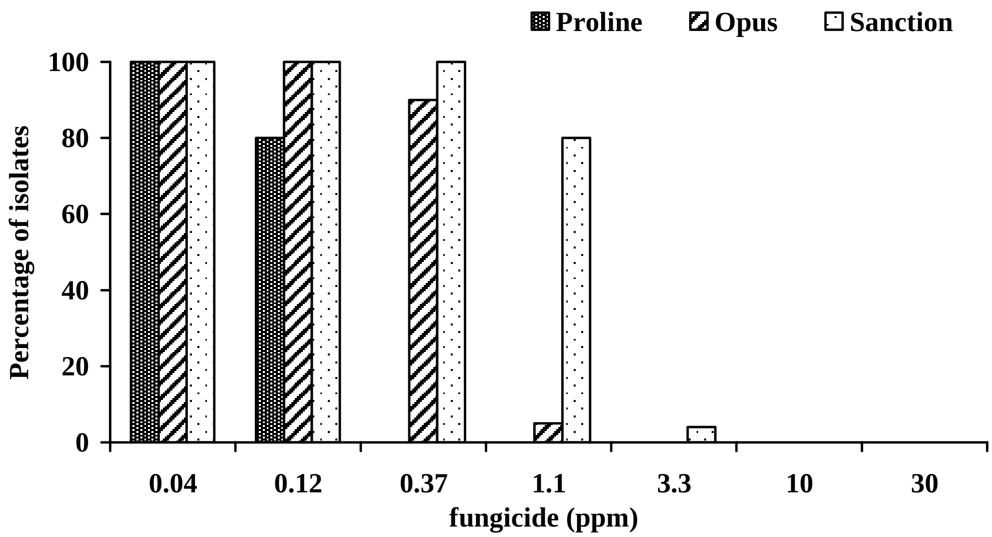

Fig. 6: Sensitivity of *Rhynchosporium secalis* isolates to prothioconazole (Proline), epoxiconazole (Opus) and flusilazole (Sanction) 2006

EYESPOT IN WHEAT

There are two different forms of the eyespot pathogen, differing in morphological characters and host range. Wheat or W-type isolates were pathogenic to wheat but caused little disease of rye, whereas Rye or R-type isolates were pathogenic to wheat and rye. Both W- and R-types are now recognized as separate species, Tapesia yallundae and T. acuformis respectively.

Populations of the eyespot fungi were preeviously investigated in Ireland in 1990. At that time the R type (*Tapesia acuformis*) predominated in all crops having replaced the previously dominant W type (*T. yallundae*) and all populations of eyespot were predominantly resistant to MBC-generating fungicides. MBC-generating fungicides have not been used to control eyespot since the 1980s.

Investigations of eyespot at Oak Park from 2001 to 2003 showed that there had been little change in species composition and fungicide resistance since 1990 (Table 2). The R type (*T. acuformis*) was still dominant but it had dropped from 89% of isolates in 1990 to 78% in 2003, with a corresponding increase in W-type (*T. yallundae*). MBC resistance was still as widespread in eyespot populations as it was in 1990, with over 90% of isolates resistant each year. This was despite the fact that MBC fungicides have not been used for eyespot control since the late 1980s. Reduced sensitivity to prochloraz was also widespread in eyespot populations occurring in 54% of isolates in 2003 compared with 31% in 1990. There was also reduced sensitivity to cyprodinil (Unix) in populations of eyespot fungi and this occurred in 24% of isolates in 2003.

Table 2: Distribution of strains and fungicide resistance in eyespot populations in winter wheat

Year	**No. of crops**	**R type (*T. acuformis*) (%)**	**W type (*T. yallundae*) (%)**	**MBC resistance (%)**	**Prochloraz reduced sensitivity (%)**	**Cyprodinil reduced sensitivity (%)**
1990	37	89	11	87	31	-
2001	36	77	23	90	45	18
2002	76	72	28	91	52	27
2003	55	78	22	96	54	24

Eyespot populations in winter wheat crops were again sampled in 2005. The results indicated a further decrease in the frequency of the R type and an increase in the percentage of isolates with reduced sensitivity to Unix. As the number of crops sampled was low (15) and only a few isolates were obtained from some crops the results may not be an accurate reflection of the real situation. Sampling was carried out again in 2006 and testing of these samples is still in progress.

MANAGING FUNGICIDE RESISTANCE

The triazoles are the most important group of fungicides that are available to cereal growers. They are used to control many diseases of cereals. It is obviously in the best interests of all involved in crop protection – growers, advisors, researchers and agrochemical personnel – that these fungicides (and indeed all fungicides) are used in such a way as to maintain their effectiveness.

FRAC (Fungicide Resistance Action Committee) is a group comprised of government and industry scientists whose purpose is to provide fungicide resistance management guidelines to prolong the effective life of fungicides and to limit crop losses should resistance occur. The general guidelines provided by FRAC are:

1. Limit the exposure of the pathogen population to the fungicide by reducing the number of applications in a growing season.
2. Avoid using fungicides as eradicants.
3. Avoid using multiple low doses and use high doses.
4. Mix or alternate fungicides with different modes of action.

While these guidelines are admirable some are clearly impractical for instance the recommendation not to use fungicides in an eradicant situation. In many crops diseases, especially a disease such as septoria, are present from an early growth stage long before a fungicide is applied. The alternative is prophylactic treatments, which can often be uneconomic, or rely on some prediction of risk such as the use of Decision Support Systems which have yet to be fully validated.

There are mixed views on the effect of dose on selection of resistant strains of a pathogen. There are instances where high doses have resulted in greater selection pressure. However evidence that *Septoria tritici* in particular has become less sensitive to the triazoles over the last ten years suggests that high doses need be used for effective control of this disease. High doses mean a rate of fungicide close to or at the manufacturer's recommended rates for their product. The use of mixtures or alternating fungicides with different modes of action is a commonly used strategy to prevent or delay resistance development. Mixtures can often give better disease control than single products.

As septoria is now resistant to the strobilurins, triazoles have become the foundation of fungicide programmes to control this disease. The current situation in regard to the sensitivity of the septoria population in Irish wheat crops to the triazoles has been discussed earlier in this paper. To maintain the current efficacy of the triazole group of fungicides to septoria they should be mixed with a suitable non cross-resistant fungicide. There are two such suitable products available in Ireland **-** chlorothalonil and boscalid.

Chlorothalonil is a broad spectrum multisite fungicide which is very active against septoria. It is a protectant fungicide and is used widely in mixtures with triazoles especially at the pre-T1 and T1 spray timings. In addition to reducing the potential for the development of insensitivity in pathogens, adding chlorothalonil to triazoles at the T1 spray timing reduces disease levels and increases yield as shown in Table 3. The response from the addition of chlorothalonil at T2 applications are less consistent but in general have been positive. There is a strong recommendation that if, at any spray application, a high level of eradicant activity is required (e.g. when a spray has been delayed) then it may be more beneficial to increase the triazole dosage and not to use chlorothalonil.

Table 3: Response from the addition of chlorothalonil at T1 application timing. 2005

T1 Treatment	Rate l/ha	Yield t/ha @ 15%		% Septoria
		Co. Meath	Co. Cork	2nd Leaf
Opus	1.0	9.5	7.6	52
Opus + Bravo	1.0 + 1.0	9.9	8.0	35
Proline	0.65	9.3	8.1	37
Proline + Bravo	0.65 + 1.0	10.0	8.8	32
Venture	1.2	9.7	8.1	35
Venture + Bravo	1.2 + 1.0	9.9	8.7	30

Boscalid in contrast is a single-site protectant fungicide with a different mode of action to that of the triazoles. In this respect, as with chlorothalonil, it compliments and improves the action of the triazoles and reduces the possibility of resistance developing to the triazoles.. It is not available as a single product but in a preformulated mixture – Venture.

Chlorothalonil and boscalid are active against all strains of Septoria and should be used in mixtures with triazoles whenever they are being applied.

It was previously thought that as all triazoles had the same mode of action there would be cross-sensitivity among the various products. As discussed earlier, there is cross-sensitivity in Septoria between tebuconazole and metconazole but not between these products and epoxiconazole and prothioconazole. Prochloraz (Sportak) which has a common biochemical mode of action and cross resistance potential with the triazoles, has less efficacy against Septoria than the leading products. However, there is evidence from recent research in France that prochloraz may be effective on the strains of Septoria that have insensitivity to the other triazoles. In fact when either prochloraz or boscalid was mixed with epoxiconazole there was a decrease in insensitive isolates. Prochloraz may then be a candidate along with chlorothalonil and boscalid to be used as a mixing partner with other triazoles such as epoxiconazole and prothioconazole in a resistance management strategy. The benefits of prochloraz in this regard will be examined in trials in 2007.

CONCLUSIONS

- Resistance to strobilurin fungicides still remains high in septoria populations.
- Septoria populations remain sensitive to the triazole fungicides epoxiconazole (Opus) and prothioconazole (Proline).
- Septoria populations are less sensitive to the triazole fungicides tebuconazole (Folicur) and metconazole (Caramba) than they were in 2004.
- There is cross-sensitivity between tebuconazole and metconazole and spraying with either fungicide rapidly selects a septoria population with reduced sensitivity to both.
- A new race of the barley leaf scald pathogen *Rhynchosporium secalis* has emerged in Ireland.
- Rhynchosporium populations have the same levels of sensitivity to triazole and strobilurin fungicides as they had in 2003.
- Populations of eyespot pathogens are still predominantly resistant to MBC fungicides and some have reduced sensitivity to prochloraz and cyprodinil.

- Triazole fungicides should be used in mixtures with non cross-resistant partner fungicides in order to reduce the risk of resistance developing in the target pathogens.

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Exploiting Pig Manure as a Nutrient Source for Cereals in Ireland

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SUMMARY

The introduction of regulations regarding the use of organic manures as part of SI 378 of 2006 [European Communities (Good Agricultural Practice for the Protection of Waters) Regulations 2006], more commonly referred to as the Nitrates Directive, has restricted the amount of grassland available to pig producers for application of their pig manure. This is causing problems for pig producers. Application of the manure to arable land is a potential solution to these problems. However, the amount of fertiliser that can be applied to a crop must be reduced where pig manure is applied. Arable growers must, therefore, be confident that the pig manure will supply the required amount of nutrients to counteract the reduction in fertiliser before they will utilise the manure. This requires that the nutrients in the manure must be available to the crop to which it is applied. Variability in nutrient content is a problem with pig manure but there are on-farm methods to determine nitrogen and phosphorus content. A review of research from across Europe indicates that the phosphorus and potassium in pig manure can be as available to crops as fertiliser sources. There is less certainty about the availability of the nitrogen in pig manure to crops but it is tentatively concluded that with attention to detail the required levels of nitrogen availability can be achieved. In particular, every effort must be made to reduce ammonia loss, the key loss mechanism associated with N in pig manure, during and after application. In the immediate future at least, this will be most easily achieved by incorporating the manure, by ploughing, within hours of application. If suitable machinery becomes available in Ireland in the future injection of the manure may be an option.

However, nutrient availability is not the only factor likely to restrict the use of pig manure on crops. Even where growers are confident that pig manure will supply sufficient nutrients to a crop there are significant logistical problems associated with the use of pig manure on arable farms. Ideally manure must be incorporated soon after application when being applied before ploughing for spring crops. Coordinating manure application and incorporation will be difficult, especially since the manure will almost certainly have to be transported from the pig unit to the arable unit on the day of application. This will be a particular problem in the

immediate future due to the lack of storage facilities on the arable farm. Additionally, in many instances efficient use of the pig manure may require investment in machinery for applying the manure, such as band spreaders.

It is concluded that where efficient use of its nutrient content is obtained pig manure can be a cost effective source of nutrients for crops. However, in the immediate future at least, practical problems associated with transport and application of the manure are likely to restrict its use in arable situations.

INTRODUCTION

Traditionally a considerable proportion of the pig manure, more commonly called pig slurry[1], was applied to grassland in the vicinity of the pig producers holding. However the implementation of the 170 kg N/ha organic N loading associated with SI 378 will restrict the amount of grassland available to pig producers for application of their manure. The amount of grassland available for pig manure application is likely to be further restricted when the current transitional provisions allowing application of phosphorus in manure to soils at soil P index 4 expires at the end of 2010. This is because many of these soils will have received manure previously and are likely to be at index 4 thereby preventing further manure application in most instances. This leaves the pig producer with a considerable dilemma – what to do with his manure. Applying pig manure to arable land is a potential solution to this dilemma that could also provide benefits to the arable producer.

There are approximately 280,000 ha of cereals grown in Ireland each year receiving considerable amounts of fertiliser nitrogen, phosphorus and potassium. Pig manure contains nitrogen, phosphorus and potassium as well as minor/trace elements. It is estimated that the annual N and P output of the Irish pig industry is in the order of 13500 tonnes of nitrogen and 2600 tonnes of phosphorus respectively, a considerable proportion of which comes from grain originating from the arable land in the first place. Using some of these nutrients from pig manure to supply the needs of crops has the potential to reduce fertiliser costs on arable farms. It would also lead to a more closed nutrient cycle which will have environmental benefits in terms of reducing the requirement for fertilisers that rely on ever diminishing resources for their production. Pig manure also contains organic matter which over time can have a positive effect on soil organic matter levels with consequent benefits in terms of soil fertility and soil structure. It is also in the interests of the arable producer to ensure that the pig producer stays in business as the pig industry is a large consumer of the grain produced in Ireland.

Applying pig manure to arable land can, on paper, seem like the ideal solution to the problems that pig producers face. However, in practice, there are a number of factors that will make

[1] The term manure is used throughout this paper to refer to what is commonly called pig slurry. It should not be confused with the organic fertiliser that arises where pigs are kept in straw bedded units. Manure is used instead of slurry to emphasise it is a fertiliser rather than a waste product requiring disposal.

arable producers reluctant to use pig manure. A key factor will be the restrictions imposed on the arable producer by SI 378. Under these regulations the amount of fertiliser N and P applied to a crop must be reduced by an amount equal to the amount of available N and P deemed to have been applied in the pig manure. This is a considerable change from the position that has existed heretofore where there were no legal restrictions on the amount of fertiliser that could be applied to a crop that had received an application of pig manure. Arable producers must be fully satisfied therefore that the nutrients in the manure will be available to the crop and that yield reductions will not occur as result of using the manure.

A second factor that is likely to restrict the use of pig manure on arable farms is the variability that is associated with pig manure. The nutrient content of fertiliser is clearly defined and its availability to the crop to which it is applied is reasonably predictable. In contrast the nutrient content of a given volume of pig manure can vary considerably and the availability of these nutrients, in particular N, to a crop can be low and variable particularly where the manure is not applied correctly. It is critical that growers have some estimate of the nutrient content of the manure being applied and that they are fully aware of how to get maximum value from these nutrients.

The machinery used to apply the manure can have big effect on the availability of nutrients in the pig manure to a crop. In many cases the most appropriate machines may not currently be available to growers wishing to exploit the manure. Therefore, investment in machinery may be required before the manure can be utilised efficiently.

A fourth factor affecting the use of pig manure on arable farms is the logistics of transporting the manure from the pig producer and applying it to the crop. Fertiliser N is relatively easily transported easily stored if necessary, and relatively easy to apply accurately and evenly. Pig manure, on the other hand is bulky to transport, requires specialised storage facilities if it is to be stored and can be difficult to apply evenly and accurately, if the appropriate machinery is not available. There is also the question of who will bear the cost of transport and application which due to the bulky nature of the product, will be higher than the cost of transporting fertiliser.

It is clear from the above that before tillage farmers decide to use pig manure as part of their fertilisation programmes they should firstly have a clear understanding of the implications involved under SI 378. They should then be satisfied that the nutrients in the manure are being fully exploited through the use of the correct application technique and timing. The objective of this paper is to collate the available information, from Ireland and abroad, regarding the use of pig manure on tillage crops, to outline what is currently considered to be the most appropriate strategy regarding the use of pig manure on arable crops and to outline current research priorities identified by Teagasc with regard to optimising the use of pig manure on crops. The paper focuses mainly on the use of pig manure as a nutrient source for cereals.

PIG MANURE AND SI 378

The use of pig manure as a source of nutrients in arable situations is not prohibited under SI 378. However, there are rules governing when and how much can be applied.

Manure cannot be applied within the closed period for organic fertiliser application which is between October 15 and January 12, 15 or 31 depending on what county you are based in. Outside of these periods manure can be applied at any time, provided weather and soil conditions are suitable. However, in practice manure should be applied as close as practically possible to when the crop requires it in order to maximise its nutrient value to a crop.

For the purposes of SI 378 pig manure, indeed all organic manures, contains two types of nitrogen, *total* organic nitrogen and *available* nitrogen. SI 378 provides figures for both types of nitrogen in various organic manures. Pig manure is deemed to contain 4.2 kg *total* N/m^3. The total nitrogen is used when calculating the organic nitrogen loading of the holding. This calculated by adding the total amount of nitrogen produced by livestock on the farm and the total nitrogen in any imported organic fertilisers. When this number is divided by the net area (grassland and arable land) of the holding the result is the organic nitrogen loading of the holding. Where manure is being imported this figure cannot exceed 170 kg organic N/ha. On an all tillage farm with no livestock the maximum amount of pig manure that can be imported is calculated by dividing the organic N limit (170 kg/ha) by the N content of pig manure (4.2 kg/m^3). Therefore, assuming that no other organic manures are being imported, the maximum amount that can be imported is 40.5 m^3/ha (~3600 gallons/acre). Where livestock are present the allowable amount that can be imported per hectare of arable land may be lower depending on the stocking density of the farm. For the majority of tillage farmers that do not have intensive livestock enterprises this organic nitrogen limit is unlikely to prevent the use of pig manure but will dictate the amount of manure that can be imported.

Only a portion of the total nitrogen in pig manure is deemed to be available to the crop. For pig manure the proportion of total nitrogen deemed to be available to the crop is 35% in 2007, 40% in 2008 and 2009, and 50% from 2010. If 20 m^3/ha of pig manure is applied this will contain 84 (20 x 4.2) kg total N/ha, but in 2007 only 35%, or 29.4 kg N/ha, of this is deemed to be available to the crop. This *available* N must be subtracted from the amount of fertiliser N allowed for that crop. Therefore the fertiliser N for the crop to which it is applied will have to be reduced by 29.4 kg N/ha. The reason that the availability figures increase over time is that farmers using manure as a nutrient source are expected to use it more efficiently as time goes by. The corresponding values for pig manure in Denmark and the Netherlands are 75% and 60% respectively.

For the purposes of SI 378 pig manure is deemed to contain 0.8 kg P/m^3 and it is deemed to be 100% available. The level of phosphorus in the manure will become important in determining where and how much manure can be applied after 2010 when the current transitional arrangements with regard to application of phosphorus in pig/poultry manure and spent mushroom compost expires. At that stage it will not be permitted to apply P in pig manure in amounts that exceed the P level recommended for that crop.

Pig manure can be applied one year in two without having an effect on the soil N index of the land to which it was applied. Therefore the reduction in the amount of fertiliser that can be applied will be calculated solely on the basis of the amount of available N and P deemed to be in the manure applied. Where it is applied to Index 1 soil for two years in succession the succeeding crop in the third season is deemed to be at Index 2 and the amount of fertiliser N allowed must be reduced to the amount recommended for that crop at Index 2. Similarly the amount of fertiliser P must be reduced by the amount of P applied in the manure. In practice pig manure should only be applied to land that has not received pig manure, or indeed any other organic manure, in the previous year to ensure that the soil N index remains at index 1. An application of pig manure in two successive seasons is unlikely to have a sufficient residual N effect on a crop in the third season to counteract the reduction in N fertiliser associated with moving from N index 1 to N index 2.

PIG MANURE NUTRIENT CONTENT

Pig manure contains a mixture of faeces, urine and water. The dry matter (DM) content of pig manure can vary considerably but is generally less than 10%. O'Bric (1991) reported a range in DM contents of 1-10%. In a more recent survey, McCutcheon (1997) reported DM contents between 0.4% and 13.1 % with a mean of 5.1%. Much of this variability is thought to arise as a result of varying amounts of water entering the manure either through the feed, as a result of washing regimes or to a lesser extent as a result of the amount of rainwater entering the manure.

The different production stages within pig units (sow, weaner, finisher) can lead to manure with different DM content. The samples analysed by McCutcheon were taken without agitation from different production stages within pig units which was responsible for some of the variation encountered and samples of mixed manure will be closer in composition to the mean value above. On average, manure from finishing pigs will be higher in dry matter than manure from younger pigs (an effect of house-washing frequency). On a well-run unit, with dry feed systems one can expect to produce manure with a dry matter content of 6% or more.

The variation in DM content has a considerable influence the usefulness of the pig manure for use on crops. There is generally a good relationship between the DM content of pig manure and its nutrient content (particularly N and P). As a general rule the higher the DM content the higher the nutrient content (Figure 1). This has important implications for the use of pig manure within the rules of SI 378. As outlined earlier, pig manure is deemed to contain 4.2 kg N/m^3 and 0.8 kg P/m^3 and these are the figures that are used when calculating the amount by which fertiliser N and P application must be reduced. This is irrespective of how much N and P is actually in the manure. This nutrient content would typically be found in manure with 4-5% DM. Therefore if pig manure with a greater DM content is obtained it is probable that it will have more than 4.2 kg N/m^3 and 0.8 kg P/m^3 but the fertiliser reduction is still calculated on the basis of these values. This suggests that using manure with DM in excess of 4-5% will give more nutrients for a given fertiliser reduction, thereby increasing the amount of nutrient being supplied to the crop.

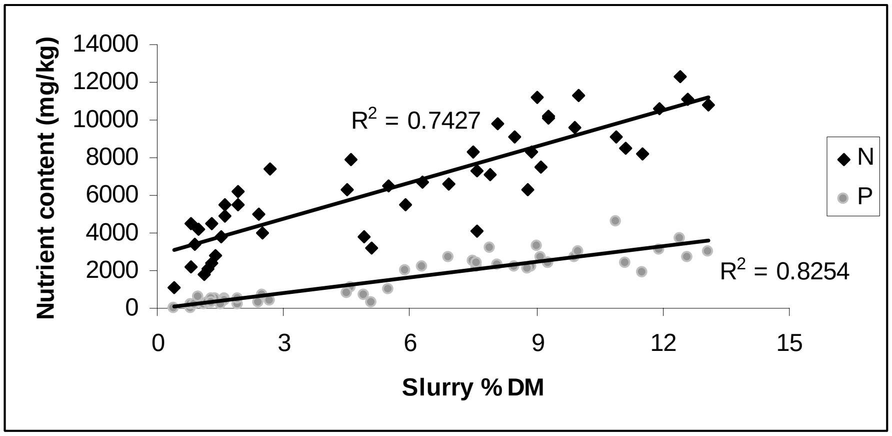

Fig. 1: Relationship between DM content of pig manure and both its N and P content of pig manure (McCutcheon, 1997).

A practical problem with pig manure is that it contains both a solid and liquid fraction. The solid portion, which is largely faeces, tends to settle to the bottom of the tank with the result that the DM content of the top portion is lower than the average while the DM content of the bottom of the tank is higher than the average (Aarnink and Huijben, 1988). This can happen quite quickly, i.e. in a matter of hours. This can have implications for use of pig manure as the nutrient content of the manure can vary depending on whether the manure came from the top or bottom of the tank. Therefore, where possible, manure should be thoroughly agitated before it is used to ensure that different tanker loads coming from the same storage tank have similar nutrient contents.

Phosphorus content and availability

Pig manure is generally regarded as being high in P. The P content of manure can range considerably. McCutcheon (1997) reported a range of 0.05 kg to 4.6 kg P/m^3 but reported a relatively good correlation between %DM and P content (Figure 1). However in the ten years since the McCutcheon survey, P levels in pig diets have been reduced so the spread in P content of pig manure is likely to be lower today.

The ratio N to P in pig manure does not match the N and P requirements of a cereal crop very well. There is more P per unit of N in the manure than the crop needs to satisfy its requirements (Schroder 2005). This means that it would not be possible to supply all of a crops nitrogen requirement without oversupplying its P requirement. It is therefore important from the point of view of preventing excessive P build-up in soils to take the P content of the manure into account in determining the amount of manure to be applied. In any case when the current transitional arrangements regarding P in pig manure expire at the end of 2010 the amount of manure that can be applied will be limited by the P requirement of the crop.

As outlined earlier, under SI 378 the P in pig manure is deemed to be 100% available meaning that a grower must subtract the total amount of P applied in manure from the amount of fertiliser P allowed for a particular crop. Therefore the P must be in a form that is available or will become available to a crop in the year of application.

Most of the P in pig manure is in the inorganic form with usually less than 10% being in the organic form (Sharpley and Moyer, 2000). Inorganic forms of P are more likely to become available quickly to a crop than organic forms. A considerable proportion of the P can be in a water soluble form which can be immediately available to plants**.** Eghball et al. (2005) concluded that except where soils were P deficient phosphorus availability for pig manure could be taken as being equal P fertiliser (100%). Some research indicates that P from manure can be more available than fertiliser P. This has been attributed to the production of organic acids as the organic matter in the manure is decomposed in the soil which reduces the extent by which P is bound to the soil. Laboski and Lamb (2003) found that, one month after application, the availability of P was greater after an application of pig manure than after an application of P fertiliser. There are some indications that where P is applied as a combination of fertiliser and organic manure that there can be a synergistic effect whereby available P levels in the soil are kept at a level higher than they would be compared to where P fertiliser was applied alone (Toor and Bahl, 1997). It can therefore be concluded that the P in pig manure is at least as available as P from artificial fertiliser where soil P levels are high. Where soil P levels are low (Index 1 and Index 2) pig manure should be used to supply only about 50% of the P requirements of the crop with the remainder applied as fertiliser P.

Other nutrients

Pig manure contains potassium (K) also. An indicative potassium content of ~2 kg/m^3 is generally used for pig manure and the K in pig manure is regarded as being approximately 90% as effective as fertiliser K. Pig manure can contain 0.15 to 0.7 kg S/m^3 with a typical value being 0.3 kg S/m^3. There is relatively little information regarding the availability to plants of sulphur in pig manure but it would appear that it is not readily available to crop plants, particularly in the year of application (Eriksen, 2002). Therefore, until research becomes available to indicate otherwise, the amount of sulphur applied to crops as inorganic fertiliser should not be reduced substantially where pig manure is applied. Pig manure can also contain copper and zinc and where repeated large applications are being made over a number of years soil levels can build up. However, copper and zinc levels in the pigs feed are now controlled by legislation and the levels in manure will have been reduced from 25 years ago so any build-up is likely to be slow. Soils should be tested periodically to monitor levels of these nutrients.

Nitrogen content

The *total* N content of pig manure can range from 1 kg N/ m^3 to 15 kg N/ m^3 (4.5 kg /1000 gallons to 68 kg/1000 gallons) but typical values would be in the range of 4-6 kg/m^3 (18-27 kg N/1000 gallons). As outlined earlier there is a good correlation between %DM and N content of pig manure.

The *total* nitrogen in pig manure is made up of two components, ammonium N and organic N (Figure 2). These two components behave differently when applied to the soil. The organic component must be broken down by soil microbes before it becomes available to plants and therefore it is a slow release form of nitrogen. The ammonium N, on the other hand, is the same form as the ammonium-N found in mineral fertiliser. It is readily available to plants when applied to the soil and can be converted to nitrate-N in the soil which is also readily available to plants. The percentage of total N present as ammonium in pig manure is typically between 60-70% but can range from 50% to 90% (Sorensen and Fernandez, 2003; Sorensen, 2003).

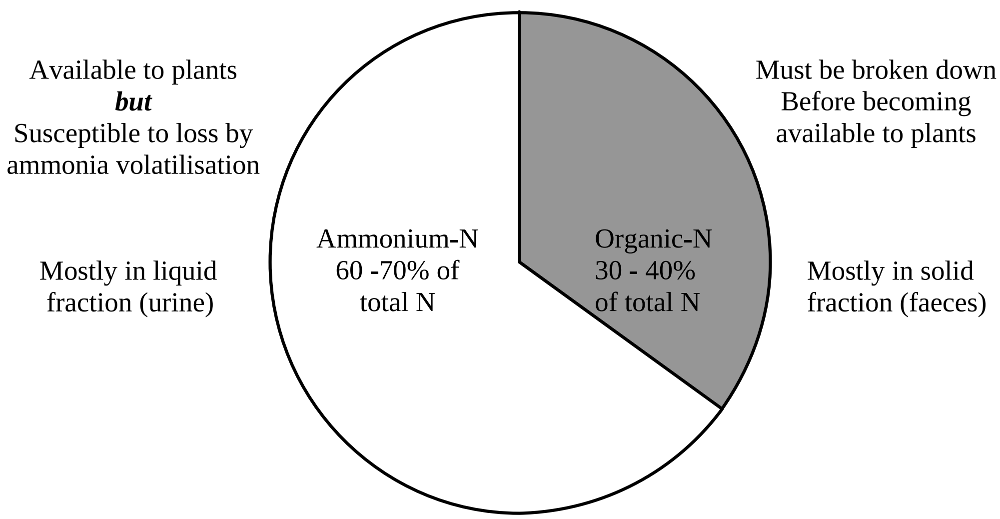

Fig. 2: Forms and distribution of nitrogen in pig manure

MEASUREMENT OF NUTRIENT CONTENT

Because of the considerable variation in nutrient content that occurs between different batches of pig manure standard nutrient content values should not be relied upon to calculate how much nutrients are being applied. Some attempt should be made to determine the nutrient content of the particular batch of manure being applied. Laboratory analysis will give the most accurate estimation of the manures nutrient content but this is likely to be impractical at farm level in most cases. However there are a number of quick on-farm tests that can be used to give reasonably good estimates of the nutrient content of manure. These include the hydrometer, the Agros N meter and the Quantofix-N-volumeter and all have been found to work well at farm level (Williams et al., 1999).

The hydrometer uses the fact that there is a strong relationship between the DM content and both the N and P content of pig manure. The hydrometer measures the specific gravity or density of the manure which is a measure of its DM content. This is then converted to a reading for total N and, where required, total P. The hydrometer method tends to give a poor estimate of the ammonium N content of the manure (Shepherd et al., 2002).

Both the Agros and Quantofix meters measure the ammonium N content (i.e. the readily available N content of the manure). They convert the ammonium N to dinitrogen gas and the subsequent gas pressure is measured and related to the ammonium N content of the manure using a calibration curve. These meters show good correlations with laboratory values (Bhogal et al., 2001). However they are somewhat more expensive than the hydrometer and somewhat less user friendly at farm level.

With all three methods obtaining a representative sample to test is the most critical part of the procedure. This is particularly important given the propensity of the solid portion of pig slurry to settle to the bottom of the storage vessel. Samples taken from a particular level in a storage tank before agitation are likely to give different results compared to samples taken from the same location after agitation.

Nitrogen availability

Only a proportion of the *total* nitrogen in pig manure will actually become *available* to crop plants in the season of application and this will largely consist of the ammonium N fraction although some of the organic N will also be released and become plant available. As we will see the proportion that will become available will depend to a large extent on how well losses of nitrogen, particularly the ammonium N fraction, from the manure during and after application are minimised.

While many nutrients in pig manure are reasonably predictable in terms of their availability to crops the availability of the nitrogen component appears from the published literature to be much more variable and difficult to predict. Given that the amount of fertiliser N applied to a crop must now be reduced where pig manure is used it is vital that the factors that are responsible for this variability are understood so that measures can be taken to minimise the variability. When calculating the reduction in fertiliser N where pig manure has been applied it is only the proportion of the total nitrogen that is *deemed* to be available to the crop by SI 378 (2006) that is taken into account. This availability is set at 35% for 2007, 40% for 2008 and 2009 and 50% thereafter. The key question with regard to nitrogen in pig manure is whether the amount of total N deemed to be available to crops under SI 378 actually becomes available to crops under Irish conditions.

Unfortunately, there is little data regarding the availability of pig manure nitrogen to cereal crops under Irish conditions. Teagasc have begun a research programme to study the availability of nitrogen from pig manure to cereal crops in Ireland, a programme that is being overseen by experts in the area from across Europe. However, in the interim, it is useful to examine research from abroad where extensive work has been carried out on the availability of N in pig manure to crops. In particular we can examine the factors that affect the availability of N from pig manure which will not differ from abroad and for which there is Irish data under grassland situations.

Where manure is to be applied to a spring sown crop application immediately before ploughing in the spring is likely to maximise the amount of nitrogen recovered from the manure by the crop. Work in Denmark indicates that when this is done all the nitrogen requirements of spring barley can be supplied by spring applied pig manure (Petersen, 1996). However, it should be remembered that this approach will quickly lead to increases in the soil P index which will prevent further applications of manure. Sorensen et al. (2003) reported, in Denmark also, that where pig manure was applied to land destined for spring barley and harrowed in almost immediately 63% of the nitrogen became available to the crop. When the manure was injected before sowing 79% of the nitrogen became available

Some model predictions indicate that where pig slurry is applied in the spring before sowing spring barley with a splash plate and ploughed down within 24 hours 35% or more of the N would be available to the subsequent crop. Ploughing within three hours would increase this to 50% or more (J Schroder, personal communication).

When surface applied to a growing winter crop in the spring the utilisation of N will often be somewhat lower than where it is applied and incorporated before sowing of a spring crop. This is because, as we will see later, there is greater potential for ammonia loss. For example, Sorensen and Thompson (2005) reported that the overall utilisation of pig manure N was greater when manure was incorporated before sowing spring barley (75-79%) than after surface application to winter wheat (59-64%). However, the utilisation of the manure N can still be high when it is applied to the growing crop. In Denmark over a series of 15 experiments there was little difference in the yield of winter wheat receiving 150 kg N ha as fertiliser and wheat receiving 50 kg as fertiliser and 100 kg ammonium N/ha as pig manure band spread onto the crop (Anon, 2001) suggesting that provided ammonia loss is minimised the availability of N in manure will be similar to the ammonium N content of the manure. For winter wheat Sorensen et al. (2003) reported that when pig manure supplying 100 kg ammonium N was applied to a crop in early May, when the crop was 35 cm high, 70% of the nitrogen became available to the crop. The crop had already received 60 kg fertiliser N/ha in March. It must be remembered that a lot of soils in Denmark are sandy in nature which will increase infiltration of the slurry into the soil and thereby reduce ammonia losses. In the UK Smith and Chambers (1992) reported a range of 30-90% (mean 60%) availability of the nitrogen in pig slurry when applied to growing cereals in the spring. In more recent experiments in the UK where pig manure was applied to winter wheat using a band spreader at GS 30 approximately 50% of the N in the manure was available for grain yield production.

However where the manure was applied in the autumn, after drilling, less than 20% of the N was available for grain yield production (Shepherd and Smith, 2003).

When applied to a standing winter wheat crop Smith and Chambers (1992) reported that reduced DM content increased the N utilisation of the slurry. They produced an equation that would indicate slurry with a DM of 4% would give an N utilisation of 50% when applied to a standing crop.

In conclusion it would appear that it should be possible to ensure that 50% of the nitrogen applied in pig manure will become available to the subsequent crop. This figure is more likely to be achieved where the manure is applied in the spring to land destined for spring cereals before ploughing and immediately incorporated. Where the slurry is applied to a growing crop 50% utilisation of the N may be possible but research is needed to confirm this under Irish conditions.

Residual N availability

Organic manures can have a residual N effect in crops succeeding the crop to which the manure was applied. This residual effect varies depending on the organic manure in question. In general organic manures with a high proportion of readily available N have a low residual effect. Therefore it can be concluded that pig manure, which can contain >70% of its nitrogen as readily available N will have a low residual value. This has been borne out by experimental evidence. Sorensen and Thompson (2005) reported that the residual effect of pig manure in the succeeding year was ~3% of the applied N. However where pig manure is repeatedly applied to a particular soil over a long number of years the residual effect is likely to increase. Sorensen et al. (2002) reported that when a single application of manure was made to a crop with a short growing season such as spring barley 2% of the N could be available as a residual effect in the following season. This figure rose to 3% after 2 yearly successive applications and to 7% after 10 successive yearly applications.

MAXIMISING N AVAILABILITY

Maximising the proportion of the nitrogen in a pig manure application that becomes available to a crop will largely depend on how well ammonia losses are controlled but will also depend on synchronising manure application with crop demand as much as practically possible.

Ammonia loss

The ammonium-N fraction in pig manure is very susceptible to loss by volatilisation, that is it escapes as ammonia gas into the atmosphere. Given the high proportion of the total nitrogen that exists in the ammonium form in pig manure it is critical that the process of volatilisation is minimised in order to minimise N loss. Any process which increases the contact between the manure and the air will tend to increase the amount of pig manure N lost via volatilisation. The main factors that affect ammonia volatilisation are speed of incorporation/infiltration into the soil following application, application method and weather conditions around the time of application.

Speed of incorporation/infiltration

The time lag between application of the manure and incorporation/infiltration of the manure into the soil is critical in determining the losses due to ammonia volatilisation. Ammonia volatilisation begins immediately after application of the manure and a large proportion of the total ammonia volatilisation from an application of pig manure will occur in the first few hours after application if the manure remains on a vegetation free surface exposed to the air (Figure 3). Using low DM manure (i.e. more watery) will increase the speed with which the manure infiltrates into the soil which will in turn reduce the amount of ammonia volatilised. However, low DM (~2%) manure will have a reduced nutrient content that may not be sufficient to counteract the reduction in fertiliser nutrients imposed a result of using the manure. Where higher DM manure is used, which will infiltrate into the soil more slowly, the key to minimising ammonia loss is where possible to incorporate the manure into the soil. Ideally, therefore the manure would be incorporated as it is spread i.e. injection type machines. Injection type machines are used widely in Denmark and the Netherlands to apply manure to arable land before subsequent ploughing or cultivation for spring crops. However, in practice these are not likely to be widely available in Ireland, at least in the short term. In most instances in Ireland there will be two separate operations, manure spreading and manure incorporation. It is essential that these two processes are coordinated to ensure that the manure is rapidly incorporated. In practice most of the incorporation will be via ploughing but non-plough cultivation methods are also effective. There is some evidence to suggest that incorporation by ploughing is more effective than incorporation with a tine cultivator, given a similar time lag between application and incorporation. This is most likely due to the fact that some manure will inevitably be left at the surface when incorporating using a tine cultivator. However, irrespective of the method rapid incorporation is vital. UK recommendations indicate that in order to conserve 90% of the ammonium N in manure incorporation should be immediate and to conserve 50% incorporation must take place within 6 hours. This obviously presents considerable practical logistical challenges.

Weather conditions at application

The weather conditions around the time of application can have a significant effect on ammonia loss. Warm, windy and sunny weather should where practically possible be avoided. Ideal weather conditions to minimise ammonia loss are overcast, cool, and calm with high humidity and perhaps light drizzle or very light rain. In practice, soil conditions and the requirement to get cultivation operations carried out in good time for sowing crops will dictate when manure is applied to spring crops before planting and the need to apply nutrients to match crop demand will dictate when manure is applied to growing crops.

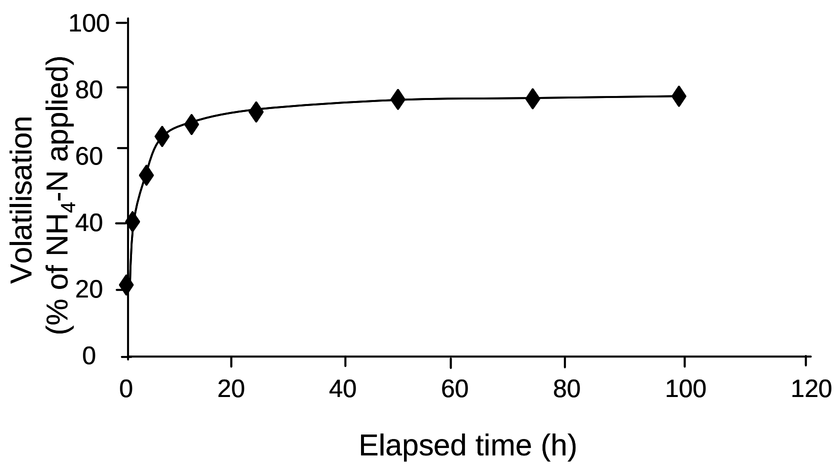

Fig. 3: Idealised curve showing cumulative volatilisation of NH_3 from slurry from the time of spreading at time zero to 96 hours later (Huijsmans, 2003).

Timing of application

The effect of timing of application on ammonia loss is important where pig manure is being applied to growing crops. Pig manure can be applied to growing crops and is carried out at farm level in other European countries. While not essential specialised spreading equipment is normally used which allows use of tramlines up to 24m. In this case incorporation is generally not practical, although it is practiced to a limited degree in other countries, so in order to minimise ammonia loss the manure should be deposited on the soil surface under the crop. Rapid infiltration of the manure into the soil will help minimise losses of ammonia. In general the lower the DM of the material applied the more rapid the infiltration. This presents a dilemma in that as outlined earlier the total N content of manure tends to decrease as %DM decreases. When applied to the soil under a growing crop some of the ammonia that would otherwise be lost can be intercepted by the crop canopy. Where the crop has entered stem elongation at the time of application it will tend to shelter the manure from wind which will also reduce ammonia loss compared to if the manure was applied to bare soil.

Nevertheless experience from abroad would indicate that the nutrient value of pig manure can be exploited successfully by growing crops. When applying manure to winter wheat in the UK Shepherd and Smith (2003) found that the efficiency of use of pig manure N and consequent grain yields were greater where the manure was applied in the spring at GS 24 or GS 30 compared to autumn application or GS 39 application with a trend towards greatest efficiency from application at GS30. Where pig manure was applied using a band spreader at

GS 30 approximately 50% of the N in the manure was available for grain yield production. However where the manure was applied in the autumn, after drilling, less than 20% of the N was available for grain yield production.

There is some evidence that splitting of manure applications on growing crops can lead to better efficiency of use by the crop of the nitrogen in the manure. In northern Germany, Sieling (2004) concluded that applying the manure in three splits increased the efficiency with which the nitrogen in the slurry was used by the crop. However from a practical point of view most manure will be applied as a single dose.

Method of application

The type of machine used to apply the manure can have a large bearing on the amount of ammonia lost by volatilisation. There are a range of machinery types that can be used to apply manure to arable land including broadcast or splashplate spreaders, band spreaders, trailing hose spreaders, trailing shoe spreaders and injector type spreaders.

Currently the most common type of spreader available is the downward facing splashplate type. Losses due to ammonia emission are often higher with this type of machine than with other types of spreader.

Band spreaders apply the manure through tubes onto the soil surface in discrete rows at regular spacing, often around 30 cm. A trailing hose is a specific type of band spreader where the tube is dragged along the soil surface and is often used on growing crops to deposit the manure onto the soil surface under the crop. A trailing shoe machine is another type of band spreader whereby a shoe attachment to the delivery tube of the spreader moves along the soil surface parting any crop and depositing the manure under the crop. These types of machine can substantially reduce ammonia loss relative to broadcast spreaders.

Injection type machines place the manure below the soil surface during application. From the point of view of minimising ammonia losses these are the most favourable type of machines.

PRACTICAL ISSUES

Machinery selection

As outlined earlier there are a range of machine types available for the application of manure. As well as varying in terms of their effect on ammonia loss they vary in terms of their relative cost, the degree of evenness of spread that can be achieved and their availability in Ireland. Technology for applying manure to arable land is now highly developed on the continent and while some of the machines types described here are not yet widely available in Ireland, they can be easily imported if required.

The downward facing splashplate spreader is the most readily available machine in Ireland currently. It is the least costly type of spreader available. However it leads to comparatively high ammonia losses and it is often difficult to achieve uniformity across the spread width or good bout matching. They also give high odour levels which may be an issue in certain areas. It is therefore not the most suitable machine type for use where high recovery of nitrogen component of the pig manure is required.

The band spreader can be somewhat more expensive than the splashplate spreader but gives reduced ammonia losses. It also allows good bout matching and gives good evenness of spread (Carton and Lenehan, 1997). They give significant reductions in odour compared to splashplate machines. Band spreaders with trailing hoses can be obtained with working widths up to 24m and therefore allow the possibility of manure application to growing crops where wide tramlines are in use. In general band spreaders are not widely used in Ireland but trailing shoe type spreaders in particular look set to become increasingly popular in grassland situations. Band spreaders may be the most suitable and practical type of machine for use in arable situations in Ireland going forward.

Injection type machines for arable situations can either just inject the manure with minimal soil disturbance or can combine the manure application with soil tillage. They give low ammonia losses but tend to be more expensive than band spreaders. Their work rate can be slower than other types resulting in higher operating cost. They offer the potential to remove some of the logistical problems associated with coordinating the spreading and incorporation operations when the manure is surface applied in that the slurry is being incorporated as it is being spread. They will also tend to give the lowest levels of odour.

With all tanker types the weight of the laden tanker can be considerable and this can lead to a risk of soil compaction. To overcome this tyre selection is crucial so as to minimise ground pressure. Alternatively, umbilical type systems could also be used which use a nurse tank located near the area of application from which the manure is applied.

Transport and storage

A key practical issue that will arise where an arable grower decides to use pig manure is how to ensure that the manure will be available in sufficient quantity for application on the arable farm on the day that it is required. This will be particularly important where an incorporation operation is being coordinated with a spreading operation. Where the pig unit is more than a few kilometres from the arable farm it is unlikely that it will be possible to transport sufficient quantities in the short-time span often associated with nutrient application windows for crops. Ideally, therefore, the pig manure would be stored on the arable farm. Realistically the amount of storage capacity on arable farms is likely to be limited currently. The only logical solution to this would be to encourage the provision of manure storage facilities on the arable farm.

MANURE TREATMENT POSSIBILITIES

Separation of pig manure

Manure separation has been proposed as a solution to the pig manure problem. Separation is a process by which a manure is divided into a dry matter rich (DMR) fraction and a liquid fraction. The DMR fraction, often referred to as the solid fraction even though it can contain 70-80% water, contains a large proportion (70-80%) of the P whereas the liquid fraction contains a large proportion (70-80%) of the nitrogen (Sorensen and Thompson, 2005; Moller et al., 2002). Separation does nothing to reduce the nutrient load of the manure, it just divides the nutrients into two separate streams. Currently it would appear it is unlikely that separation will become widespread in Ireland due to the extra cost involved. Separation may have a role to play in areas where there is intensive pig production but spreadlands are constrained by soil P levels. In these areas separation may allow more efficient exportation of the P content of the manure while the high N liquid fraction is used on traditional spreadlands locally.

In terms of nutrient value to crops Sorensen and Thompson (2005) indicated that there was little difference in terms of crop N uptake between applying unseparated manure or independently applying the two separated fractions to a crop. However they did show that overall the N could be used somewhat more efficiently where the DMR fraction was applied to spring barley (incorporated before sowing) and the liquid fraction was applied to a growing winter wheat crop. This may be because better flow properties of the liquid fraction facilitates soil infiltration when applied to the growing crop thereby reducing ammonia volatilization (Stevens and Laughlin, 1997).

In Denmark, where separation of slurry occurs to some extent on a commercial basis, there is little demand for the solid fraction which is high in phosphorus. An interesting development currently being explored there is where the solid fraction is being incinerated to give energy and a P-rich ash. This ash is then combined with wood ash from Sweden, which is K rich, to give a fertiliser similar in form to normal mineral fertiliser.

THE ECONOMIC VALUE OF PIG MANURE

The value of organic manures, including pig manure, will depend on the amount of nutrients, particularly N, P and K, that are in the manure. Organic manures can also act as a source of organic matter. As pointed out earlier there is considerable variation in the nutrient content of pig manure and consequently the economic value of the manure to the tillage farmer will vary depending on the nutrient content.

An estimation of the nutrient value of a typical pig manure with for example 4.3% DM, containing 2.1 kg available N/m^3, 0.8 kg P/m^3 and 1.9 kg K/m^3 (10.4, 4.1, 11.8 kg N, P and K/1000 gallons) can be easily calculated (Table 1). In this example the value of N, P and K has been taken to be 73 c/kg, 131 c/kg and 39 c/kg respectively, which is equivalent to CAN @ €197/t, and 0:7:30 or 0:10:20 at ~ €210/t. Using these costs the value of the nutrients in 1 m^3 (220 gallons) of typical pig manure is ~ €3.32 (Table 1). For the purposes of this calculation 50% N availability is assumed. Obviously where a lower N availability is assumed the value of 1 m^3 of manure will be lower and vice versa. Therefore where 22.4 m^3/ha (2000 gallons/acre) of this manure is applied to land there is potential saving of ~ €74/ha (~€30/ac) in terms of fertiliser costs. The actual value will depend on a) any costs incurred by the tillage farmer in obtaining and spreading the manure and b) how effectively the grower utilises the manure. In many cases the costs of transporting and spreading the manure may be borne wholly or in part by the pig producer.

Table 1: Economic value of pig manure

Nutrient	1 m^3 (220 gallons)		11.2 m^3/ha (1000 gals/acre)		22.4 m^3/ha (2000 gals/acre)	
	kg	€	kg	€	kg	€
Nitrogen						
Total (kg)	4.2		47		94	
Available (kg)	2.1		23.5		47	
Value (€0.73/kg)		**1.53**		**17.2**		**34.3**
Phosphorus						
Total (kg)	0.8		9		17.9	
Available (kg)	0.8		9		17.9	
Value (€1.31/kg)		**1.05**		**11.8**		**23.4**
Potassium						
Total (kg)	1.9		21.3		42.6	
Available (kg)	1.9		21.3		42.6	
Value (€0.39/kg)		**0.74**		**8.3**		**16.6**
Total		**3.32**		**37.3**		**74.3**

Note: No account is taken of transport and spreading costs.

RESEARCH NEEDS

It is clear from the information presented above that there is a requirement for a considerable amount of research regarding the use of pig manure as a source of nutrients for arable crops in Ireland. There is a need to establish the availability of N from pig manure to both spring crops before sowing and growing winter crops under Irish conditions. The most appropriate methods of applying manure in the different situations must also be assessed. This would include an evaluation of the different machine types that are currently available abroad. These issues are currently being addressed by Teagasc in a cross-centre collaborative research project. The suitability of quick measurement methods for on-farm nutrient determination of pig manure must also be assessed under Irish conditions. There is a requirement to determine the location of suitable arable ground relative to the units where the slurry is being produced to assess the viability of transporting slurry from the pig unit to the arable ground. It may also be appropriate to make an assessment of manure treatment technology to determine if it has any place in Ireland.

PRACTICAL RECOMMENDATIONS

Growers wishing to exploit pig manure where it is locally available, and are not limited by the organic nitrogen ceiling of 170 kg organic N/ha, should consider applying manure to stubble ground immediately before ploughing for spring crops such as spring barley or spring wheat. For reasons outlined earlier, rapid incorporation is essential in order to minimise the N loss and thereby get the full value from the manure. This will obviously cause logistical problems on many farms. Where available band spreaders or trailing shoe type applicators should be used instead of downward facing splashplates to reduce N loss and increase the evenness of spread. In general modest application rates should be used -17m^3- 22m^3 (~ 1500-2000 gallons/ acre). This ensures that mineral fertiliser can also be applied which reduces the crops reliance on nutrients from the manure, thereby minimising the effect of any variability associated with the manure nutrient content.

Where possible the grower should have some idea of the DM and/or nutrient content of the manure. Manure with a DM content less than approximately 4% DM is likely to have less nitrogen and phosphorus in it than what will have to deducted from the fertiliser allowance for that crop (you must deduct what is deemed by SI 378 to be in the manure not what is actually in it, unless you have a certified analysis to the contrary).

While manure can be applied to winter crops in the spring the machinery to do this, particularly where wide tramlines are used, is not yet widely available in Ireland and therefore this is not currently a realistic option. Applying manure in the autumn is not advised as there is a high risk that nutrients, particularly nitrogen, will be lost over the winter period.

CONCLUSIONS

- Pig manure has potential as a cost effective source of nutrients for arable crops and can lead to considerable savings in fertiliser costs.

- Logistical problems exist that militate against the use of manure, such as the requirement to spread and incorporate within a short time frame.

- Lack of manure storage facilities on arable farms where the manure is to be applied will also cause problems.

- Achieving efficient use of the nutrients in the manure requires that
  - The nutrient content of the manure is known
  - The manure is applied evenly and accurately
  - The application method minimises ammonia loss
  - The manure is rapidly incorporated

- Applying pig manure to growing crops may be feasible but requires research before it can be recommended.

- Applying to land destined for spring barley or spring wheat immediately before ploughing appears to be currently the most practical place to use pig manure.

- Applying to growing crops may be more feasible in the future when the technology for applying slurry to crops becomes more widely available in Ireland.

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Potential of Organic Tillage in Ireland

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SUMMARY

Organic farming is now practiced worldwide and in the EU it is governed under a set of standards given recognition under EU law. The area under organic management in Ireland is about a quarter of the EU average and the area under organic tillage only about 1/16 of the EU average. In recent years there has been substantial growth in the area under organic management in Ireland but from a low base. The organic food market has grown rapidly in recent years. The Teagasc organic experimental unit is now in the final year of a seven year rotation and highly satisfactory yields and quality have been maintained. The derogation allowing conventional ingredients in organic rations and the importation of feeds have reduced the potential market for Irish organic feeds so that they make up only about a ¼ of feeds fed to Irish organic stock. There are very solid indications that there is strong growth potential in the Irish organic feed market and prices are currently at their highest ever. Proposed changes for the organic supplementary measure in REPS 4 include payments for partial conversion to non-REPS farmers, extra payments for growing green manure during conversion and exchange of land parcels between organic farmers to facilitate good crop rotation. These changes combined with good potential margins and good market growth potential indicate that tillage farmers should give serious consideration to at least, partial conversion to organic production.

INTRODUCTION

What is organic farming? It is defined by the Department of Agriculture and Food as: “a farming system which relies on crop rotations, the recycling of farm-produced organic materials i.e. crop residues, animal manure, legumes, green manure and off-farm organic wastes and on a variety of non-chemical methods for the control of pests, diseases and weeds. Synthetically compounded fertilisers, pesticides, herbicides, growth regulators and livestock feed additives are excluded or severely restricted. The products and methods of genetic engineering are also strictly prohibited.”

Organic farming is governed by European Council Regulation 2092/91 as amended. Three Organic Certification bodies are approved by the Department of Agriculture and Food to operate the inspection and certification system. Their application of the rules is set out in a document called 'The Standards for Organic Food and Farming in Ireland', which has been agreed between the three certification bodies and approved by the Department.

Increasing concerns of consumers about food safety and environmental issues have contributed to the growth in organic farming in recent years. It has developed rapidly on a worldwide basis and is practiced in approximately 120 countries. The area of agricultural land devoted to organic production continues to increase and latest estimates indicate that there are over 31 million hectares of farmland now managed organically on over 600,000 farms worldwide. The main markets for organic products are in Europe and North America and growth is continuing in these markets as well as in many other countries.

Area farmed

At EU-25 level, the certified organic and in-conversion area covered 5.7 million ha and represented 3.6 % of the Utilised Agricultural Area in 2003. In EU-15, certified organic and in-conversion holdings increased from 29 000 in 1993 to more than 140 000 in 2003 and account for about 2% of all holdings. For EU-N10, organic holdings represent a share of 0.25% in total holdings. Italy had the largest number of organic holdings (31% of EU-25 total), followed by Austria, Spain and Germany. Five Member States had a share of organic holdings in total holdings above 3%. It grew by about 25 % a year between 1993 and 1998 and, since 1998, is estimated to have grown by around 30 % a year. In some Member States, however, it now seems to have reached a plateau. Our nearest neighbour, the UK, had a total of 619,852 ha farmed organically at the end of 2006. This area is farmed by 4,285 farmers and growers giving an average of 145 ha per farm.

At the end of 2006 there were 1,260 registered operators in Ireland of whom 1,104 were farmers/growers. Between them they are farming 39,665 ha which represents approximately 0.9% of Utilizable Agricultural Area and the average holding size is approximately 36 ha. This organic area is made up of 26,137.25 ha which is fully organic and 13,810.05 ha which is in conversion to organic. This is well below the EU-25 level of 3.6 %. The National Steering Group for the organic sector has set a target of 3% of UAA to be either fully organic or in conversion by 2010. This is an ambitious target given the current position.

Table 1: Changes in farmer numbers and organic area since 1997

Year	Producers	Total Organic Area – Ha.*
1997	583	18,687
1998	762	22,411
1999	972	29,360
2000	852	27,231
2001	918	30,017
2002	923	29,850
2003	889	28,514
2004	897	30,670
2005	978	35,266
2006	1104	39,947

*(in conversion and full organic status)

From the figures above it can be seen that the area farmed organically grew rapidly between 1997 and 1999 increasing by over 57% or 10,673 ha, however between 1999 and 2004 the area seemed to plateau, fluctuating between 27,231 and 30,017 ha. There was another spurt of growth between 2003 and 2006 with a 40% or 11,433 ha increase in area over the three years.

The market for organic food

The highest shares of organic food in total food products turnover were observed in Denmark (5%), Sweden (3%) and Germany (2.6%).

However, the share of organic food in total food turnover varied significantly by individual product groups. On EU-15 average this share was 1.8% for cereals, 1.6% for beef, 1.3% for vegetables and fruit, 1.3% for eggs and 1.2% for milk and milk products in 2001. There has been considerable growth in the market of organic products in Europe in recent years. Experts estimate that in the established organic markets like Austria, Denmark, Germany, the United Kingdom and France average growth rates will not reach more than 10 percent per year over the period 2002-2007, however the Soil Association reported growth of 30% in the UK in 2006. The Irish organic market was worth €66 million in 2004 or approximately 1% of the total food market.

As a general rule, organic products receive a higher price than conventional products, but prices diverge depending on the country and on the product. Results from Organic Marketing and Rural Development Project surveys in the EU-15 show that in some cases price premiums for organic products, i.e. the relative price difference between organic and conventional products, are lower for consumer prices than for farmer prices (milk, eggs, potatoes), but the opposite is true for other products (wheat, apples, pork, beef).

The current position of organic tillage

Only about 1.5% of organically managed land in Ireland is used for tillage and most of the produce is kept on the farms for home consumption. Only a small proportion of organic grain is traded and most of this is farm to farm trading. In 2006 there were 72 registered organic farmers with a tillage enterprise farming 620 ha of tillage crops. This gives an average of 8.6 ha of tillage area per farmer with approximately 2/3 of these farmers having less than 10 ha of crops.

While detailed data is not available for the type of crops grown it is evident that there are more spring than winter crops grown. No particular species seems to dominate spring plantings with oats, wheat and barley and some triticale being grown. Oats and triticale appear to dominate winter plantings with a small amount of wheat and little or no winter barley being grown. Protein crops are grown by very few producers with small amounts of beans, peas and lupins being produced.

Precise data for yields achieved on farms is not available but generally yields of spring cereals range from 2.5 to 5 t/ha with average yields of approximately 3.5t/ha at 20% moisture. Winter crops generally have higher yield potential and on the limited number of farms growing them produce yields of 5 to 9 t/ha with average yields of approximately 6.5t/ha at 20% moisture. The small amount of protein crops grown produce yields in the range of 2 to 3.7 t/ha with yields of 3t/ha or less on average. It can be assumed, therefore, that total annual production of organic cereals and protein crops is in the region of 2,200 t.

In the UK, at the end of January 2006, there were approximately 800 organic farms with a tillage enterprise with an overall average area of 73 ha of crops per farm. The total cropped area was 58,482 ha made up of 47, 694 ha of cereals and 10,788 ha of other crops (DEFRA). Total production of cereals in 2006 is estimated at 151,319 tonnes (S. Briggs Abacus Associates). Average yield across all crops was approximately 3.5t/ha which is on a par with Irish yields. UK prices are also on a par with Irish prices and the UK is less than 40% self sufficient in organic cereals and proteins. Table 2 below shows the estimated UK production for 2006.

Table 2: Estimated UK Organic Cereal, Pea and Bean Production for 2006

Crop	Hectares	Tonnes	Value (£)
Wheat - feed	15602	55386	7407835
Wheat - milling	3900	13846	2284659
Oats-feed	4611	17292	1642740
Oats milling	1153	4323	472828
Barley - feed	6187	21346	2508136
Barley - malting	1547	5336	813810
Triticale	3034	13653	1718003
Peas	309	1080	176866
Beans	5863	19056	2727397
Totals	**42,206**	**151,318**	**19,752,275**

(S. Briggs Abacus Associates)

In 2003 there was around 1.3 million ha of organic and in-conversion arable crops in the EU-15; this constitutes 25% of the total organically managed land. Of the 1.3 million ha, 0.30 million ha are located in Germany, 0.28 million ha in Italy, 0.16 million ha in Spain and 0.12 million ha in France. Cereals make up the largest part of the arable area and represented about 70% of the total. The share of organic and in-conversion cereals in total cereal area was highest in Portugal (6.6%), Italy (5.0%) and Austria (4.9%). Production of organic cereals and pulses in the whole EU 25 in 2003 was 2.79 million tonnes and the estimate for 2004 is 2.91 million tonnes.

ORGANIC TILLAGE RESEARCH AT OAK PARK

The overall objective of the research at Oak Park organic unit is to evaluate production systems designed to increase the yield and quality of cereal/protein crops grown in an organic rotation. A single stockless 7-year rotation (winter-wheat, potatoes, oats, legume, spring barley followed by two years of grass/clover) with three replicates has been established. Farm yard manure is applied at 25 t/ha before the potatoes and before the barley. 2005/2006 was the sixth year of the seven year rotation and the current production year will see the completion of a full cycle at the site.

Winter wheat and triticale crops were sown on 4th November 2005 and the winter oats were sown on 21st November. Establishment was satisfactory, with crops outgrowing weeds which emerged during winter/spring. The spring barley plots were sown on 22nd March 2006 and again establishment and growth were satisfactory, such that weed competition was not severe.

Grain and straw yields with quality parameters are presented in Table 3. Satisfactory grain yields were achieved, particularly of winter wheat. Grain yield of the cultivar Deben (7.2 t/ha) is similar to grain yields obtained in trials where winter wheat is grown under a conventional system, except that no fungicide was applied. The winter oat cultivar Jalna also yielded particularly well, while yield of Barra was somewhat disappointing.

Table 3: Yields of grain, straw and quality parameters of 2006 cereals

Crop	Cultivar	Grain Yield (t/ha)	Specific Wt (kg/hl)	Screenings (%)	Straw Yield (t/ha)
Winter Wheat	Deben	7.2	76.4	0.22	11.9
Triticale	Fidelio	5.6	72.7	0.27	10.8
Winter Oats	Barra	4.8	57.0	1.85	11.8
Winter Oats	Jalna	6.2	52.4	3.56	12.5
Spring Barley	Tavern	4.8	67.9	0.81	4.1

Spring lupins were sown on 28 April 2006. The seeding rate was 100 seed/m^{-2}. Due to excessive weed competition in previous seasons the single stem type cultivars were abandoned in favour of the branched stem cultivar “Bordako”. The branched habit ensured that competition for light prevented weeds from dominating the canopy. In 2006, wild oat infestation seriously competed with the lupin crop and it was barely possible to hand rogue the plants. While satisfactory yield and protein content were attained (Table 4) the branched cultivars are late maturing. This results in harvesting operations being carried out under less than favourable weather conditions. An additional consequence of delayed harvesting is the difficulty in establishing the subsequent over-winter green cover crop.

Table 4: Grain yield and quality parameters of Lupin, 2006

Cultivar	Grain Yield (t/ha)	DM (%)
Bordako	2.1	79.8

The area for potato planting was ploughed in February then tilled and de-stoned in late March. Three potato cultivars Orla, Setanta and Sante (Table 5) were planted on 10th May 2006. The cultivar Orla was bred at Oak Park and selected as an early maturing type, while cultivar Setanta, also bred at Oak Park, is a blight resistant main-crop type. Sante is an established commercial cultivar in The Netherlands. The weeds emerging after planting were removed mechanically and the drills ‘moulded up’. This provided an acceptable level of weed control. Met Eireann blight warnings were utilised to schedule three applications of copper (6th July; 24th July; 2nd August) for the control of late-blight. The Orla plots were harvested on 1st September the Sante plots on 8th September and the Setanta plots on 22nd September 2006. Graded yields and total tuber yield is presented in Table 5. The late sowing date combined with the “dry” year mitigated against high yields, particularly for Orla and Sante. Setanta provided the greatest proportion of its yield in the commercially valuable 45-80 mm ‘ware’ fraction.

Table 5: Graded yields (t/ha), total tuber yield and percent dry matter for three potato cultivars, grown in 2006

Cultivar	<40 mm	40-45 mm	45-60 mm	60-80 mm	>80 mm	Def.	Total Yield	DM %
Orla	1.3	1.7	12.6	3.8		1.8	21.2	20.9
Sante	2.5	3.1	15.5	3.2		0.9	25.2	24.2
Setanta	1.1	0.8	10	18.3	1.7	0.7	32.6	21.8

In a stockless organic rotation the 2-year break crop of grass/clover ley, which is cut and mulched regularly during the growing season, is a crucial fertility building step. This crop is normally established by undersowing the spring barley. However, in 2005, white clover growth in the sward was not satisfactory. In 2006 the grass/clover ley break crop, which had attained poor establishment in 2005, was re-sown by 'stitching' red clover into the swarth using a Vaderstad Super Rapid S300 drill. Furthermore in 2006 after harvesting the barley crop, the stubble was tilled using a Simba Horsch Terrano 3FX cultivator and red clover was sown at 10.8 kg/ha on 21st Aug.

Another feature of stockless organic rotations is the need to establish an autumn cover crop to prevent the leaching of nitrate into the subsoil. In 2006, Black Medic (*Medicago lupulina*) was sown after the cereal crops were harvested. It is a trifoliate plant, being a winter or summer annual with prostrate or ascending stems. The root system consists of a coarse branching taproot that can form nodules. The roots add nitrogen to the soil by forming an association with rhizobial bacteria. This plant is known to thrive in areas with full to partial sun, moist conditions and soil containing loam, clay-loam, or gravel. Because it can tolerate shade, it is hoped that black medic will provide the under-story species for volunteer cereals and grasses thus adding to the reserves of soil nitrogen in addition to reducing leaching of soil nitrate. Vigorously growing plants have a symbiotic relationship with the mycelial growth of beneficial fungi. These mycorrhizae are especially important for uptake of nutrients which do not readily move through the soil, such as phosphorous and many of the micro-nutrients. Organic arable rotations are particularly reliant on mycorrhizal associations to sustain soluble nutrient availability and facilitate plant growth.

CURRENT AND FUTURE MARKETS

Cereals for human consumption

Animal feeds make up the largest part of the market for cereals and protein crops in Ireland but there is a growing demand also for product for human consumption. The only substantial outlet at present for cereals for human consumption in Ireland is for breakfast cereals. In 2006 it is estimated that approximately 1,100 tonnes of organic oats was imported for breakfast cereal production and about 100 tonnes of Irish grown oats was used giving a total demand of around 1,200 tonnes.

Animal feeds

Because organic concentrate feeds were in short supply across the EU a derogation was introduced in 1999 which allowed a limited proportion of conventional feedstuffs in the diet. This required prior permission where a farmer was unable to obtain feed exclusively from organic production. Certain conventional feeds were not allowed; among these were all GM products and solvent extracted feedstuffs. Up until 24th August 2005 up to 10% of total dry matter intake of a limited range of conventional feedstuffs was allowed on an annual basis for herbivores (cattle, sheep, goats etc.). However for short periods of feeding such as during the housing period or at weaning, the non-organic allowance could be increased to 25% of the daily diet provided the total non-organic feed remained within the annual allowance. For other species e.g. pigs and poultry the allowance was 20%.

As organic feed became more available in the EU, after 24th August 2005 a new derogation was introduced and these allowances were reduced to 5% for herbivores and 15% for other stock. This phase of the derogation ends on 31 December 2007; from then on no conventional feedstuffs can be fed to herbivores. The allowance for other species will be reduced to 10% from that date and will be reduced to 5% from 1st January 2010. From 1st January 2012 the derogation ceases for non-herbivores and no further conventional feedstuffs will be allowed.

The feed derogation was availed of by the majority of organic livestock producers who generally bought in locally grown cereals and fed them within the limits allowed. Compounders also availed of the derogation by including conventional ingredients in their compound at rates which stayed within the derogation at the recommended feeding level. It was possible to meet most if not all of the concentrate requirements of many classes of livestock from the conventional sources permitted within the derogation (see table 6).

Table 6: Examples of non-organic feed allowances

	Daily DM Intake (kg)	Non-organic DM allowed (kg/day) 5%	25%
Suckler cow (600kg)	15	0.75	3.75
Weanling (240kg)	6	0.3	1.5
Finishing animal (550kg)	13.75	0.68	3.44
Dairy Cow	17	0.85	4.25

Current size of market

In 2006 approximately 3,100 tonnes of organic compound ration was imported into Ireland; the majority of this was pig and poultry feed. When the inclusion of conventional ingredients is allowed for it is estimated that approximately 2,500 tonnes of this was made up of organic or in-conversion ingredients. There is one plant producing feed for organic fish farms and it used approximately 3,500 tonnes of imported organic ingredients. Therefore a total of approximately 6,000 tonnes of organic feed was imported in 2006.

Since no more that 100 tonnes of Irish home produced cereals found its way into the market for human consumption it can be estimated that approximately 2,100 tonnes of Irish organic cereals and proteins were fed to livestock on Irish organic farms. In addition to this there is an unknown amount of conventional feed used by farmers who availed of the derogation. This could easily amount to 1,000 tonnes or more. The size of the Irish cereals and proteins market for 2006 was therefore at least 10,900 tonnes (see table 7).

Table 7: Irish Organic Cereals and Proteins - Market Volumes

Market	Imported (t)[1]	Home (t)[1]	Total (t)[1]	Organic (t)[2]
Human Cons.	1,100	100	1,200	1,200
Livestock	3,100	3,100	6,200	4,600
Fish farms	3,500	-----	3,500	3,500
Totals	7,700	3,200	10,900	9,300

1. Including conventional feedstuffs inclusion allowance.
2. Organic portion of total.

Future demand

There are several factors which will drive demand for organic cereals and protein:

- **Organic Fish Feed** – the only plant producing organic fish-feed in the country is seeking to expand production and has a capacity to use 8,000 tonnes of organic wheat if fully dedicated to organic production.

- **Organic Dairying** – Glenisk Dairies recently announced plans to expand production following an investment in the company by Danone through its American subsidiary Stoneyfields Dairies. It is planned to expand to 100 suppliers in the Republic from the current 15; this entails an expansion from approximately 750 organic dairy cows to 5,000 over five years. Assuming a conservative annual concentrate requirement of 750 kg per cow (including replacements) this would produce a demand for 3,750 tonnes.

- **Ending of the Derogation** – without any expansion in demand there will be a requirement for at least 1,000 tonnes of extra feed to replace the Irish conventional feed used under the derogation.

- **Import Substitution** – currently approximately 7,700 tonnes of organic feed and feed ingredients are imported most of which can be produced here. Assuming that most of the cereal component of these imports was to be replaced with Irish grain it would create a demand for at least 5,000 tonnes.

- **Expansion in Meat Production** – there is a steady increase in home market demand for beef, lamb, pig and especially poultry meat. Most organic pig and poultry meat consumed in Ireland is imported and there are developing export opportunities for beef and to a lesser degree lamb. While there is real potential for growth in this sector at this stage it would be difficult to put an estimate on the demand for feed which might arise from it.

Taking all these factors into account there is potential annual demand for at least an additional 18,000 tonnes of Irish home-produced cereals within the next five years. Assuming a yield of 5t/ha this equates to about 3,600 additional hectares; this represents and six-fold increase in organic tillage area.

POTENTIAL RETURNS FROM ORGANIC TILLAGE

The vast majority of organic farmers and growers are participants in the Rural Environment Protection Scheme (REPS) and payments through the scheme have a big positive impact on returns. Achieving good yields and a premium price for the product can also substantially add to returns and as in all farming enterprises controlling costs is essential for maintaining good margins.

REPS

REPS 3 ended in autumn 2006 and currently there is no REPS scheme available to farmers. REPS 4 is due to commence in the first half of 2007. The proposed scheme will have many similarities to REPS 3 but there are some important proposed changes for organic farmers. The main proposed changes are:

- Farmers may opt to convert all or part of the holding and may participate in this measure on a stand-alone basis outside of the general REPS programme. Where part of the holding only is converted the Good Agricultural and Environmental Conditions and Statutory Management Requirements of the Single Payment Scheme must be respected on all of the holding.

- In the interest of crop rotation and optimising output, organic producers may apply to exchange parcels of full organic status.

- The payment rate will be increased for the conversion period for conventional stockless tillage producers who participate in the stand alone organic measure only, and grow green manure during the 2 year conversion process. This payment is justified on the basis that there is no market return on the area during conversion. The objective of this is to maximise the incorporation of organic matter in preparation for organic production. Table 8 below shows the main changes to organic payments.

Table 8: General and Organic REPS payments

General REPS Programme (Core measures plus options)	€234/ha up to 20ha €205/ha for next 20ha up to 40 ha €82/ha for the next 15ha up to 55ha €10/ha thereafter
Organic Farming Organic Farming (55 ha)	€212/ha in conversion up to 55 ha and €30/ha thereafter €106 /ha in full organic status up to 55 ha and €15/ha thereafter
Organic Farming (≤ 6ha)	€283/ha in conversion €142/ha organic status
Organic Farming additional option (non-Reps stockless farmers) growing green cover during conversion period	€240/ha per year up to a maximum of 40 ha for the two years of conversion
Accumulation of Aid Organic Payment **Plus** REPS basic **Plus**	Any one of; Linnet Rare Breeds Traditional Enterprises Riparian Zone

Example: Under the proposed REPS 4 scheme a conventional stockless tillage farmer with, say, 100 ha who wanted to partially convert to organic production has two options:

1. **Put the entire farm into REPS** and convert part of the holding, say 55ha, which is the cut off point for the high level of organic payments. The rest of the farm (45ha) would continue to be farmed conventionally within REPS. The farmer is also entitled to opt for another of the Supplementary Measures shown above, e.g. Linnet.

2. **Convert 40ha to organic status** while remaining in conventional production outside of REPS on the remaining 60ha. The farmer would then be entitled to the organic supplementary measure payments from REPS and could opt for the proposed new Organic Farming additional option payments provided the farm was stockless (i.e. all tillage).

Payments have been capped at €450 per hectare (if the Organic Farming in-conversion payment and Organic Farming additional option payment were added they would come to €452). The purpose of this proposed new payment is to encourage specialised conventional tillage farmers to convert land which has been in conventional tillage and to build up fertility using green manure which is mulched-in to provide fertile condition for the start of organic production in year three.

During conversion the cost of establishing the green manure crop and mulching it a number of times per year should be offset against the payments.

The two options for this farm are compared in Table 9 over the five years which is the minimum time which the farmer must sign up to.

Table 9: Comparison of payments: REPS vs. non-REPS partial organic conversion on 100 ha stockless tillage farm over five years

Payment Type	**REPS** – 55 ha organic, 45 ha conventional		**Non-REPS** – 40 ha organic, 60 ha conventional	
		€		€
Basic REPS	10,055/yr for 5 years	52,300		0
Conversion Organic Payment	55 ha @ €212 for 2 years	23,320	40 ha @ €450* for 2 years	36,000
Full Symbol Organic Payment	55 ha @ €106 for 3 years	17,490	40 ha @ €106 for 3 years	12,720
Supplementary Measure e.g. Linnet	€1,300 for 2 ½ ha for 5 years	6,500		0
Total (for 5 years)		**99,610**		**48,720**

* Payment capped at €450/ha

Production margins

Being such a small sector there is very little information on margins achieved in organic tillage. Around 200 tonnes of organic grain was bought by merchants or processors from Irish farmers in 2006 with most trade being from farm to farm. However demand has been strong since the harvest and there are no stocks of Irish organic grain now available to buy. Prices for grain off the combine last harvest were in the region of €240 to €260 per tonne while farmers selling stored grain in bulk post harvest were asking €260 to €300 per tonne collected depending on species and quality. Some grain is sold in bags for considerably higher prices.

The following (table 10) is an example of a possible gross margin from a cereal crop assuming good management. A yield of 5t/ha (2t/ac) at 20% moisture is assumed; this would be considered an above average yield for a spring crop and below average for a winter crop. All machinery work is by contractor.

Table 10: Estimated Gross Margin for Organic Cereal Crop

	€/Ha
Output	
Grain (5t/ha @ €240/t)	1200
Straw	75
Total Output	1275
Material Costs	
Seed 190kg @ €600	114
Lime, organic fertilisers	100
Total Materials	214
Margin over materials	1061
Machinery Hire + Miscellaneous	370
Gross Margin	**691**
+ Non-REPS organic payment*	106
Margin Excluding Entitlements	**797**
+ REPS/organic payment	*288*
*Margin Excluding Entitlements**	***979***

* After conversion is complete – fully organic.

Table 11 below gives and indication of the effect of variations in price and yield on gross margin.

Table 11: Effect of Price and Yield Variation on Gross margin (€/ha) Excluding Organic/REPS/Entitlement Payment

		Yield t/ha		
€/t	**3.5**	**5**	**6.5**	**8**
125	-71.5	116	304	491
150	16	241	466	691
200	191	491	791	1091
240	331	691	1051	1411
270	436	841	1246	1651
300	541	991	1441	1891

CONCLUSIONS

1. The EU and world markets for organic food continues to grow as does the land area under organic management. The Irish market has grown too but both production and organic land area are lagging far behind the EU average.

2. The area under organic tillage is tiny by EU standards and most producers have very small amounts of production. Yields are on a par with those in the UK.

3. Six years of organic production at Teagasc Oak Park using a stockless rotation has shown that satisfactory yields can be maintained using a two year fertility building break and imported farm yard manure.

4. There are strong indications that there is potential for strong growth in Irish organic cereal and protein crop production albeit from a low base.

5. Proposed changes to REPS 4 which allow; non-REPS farmer to draw down organic payments on part of their land, extra payments for growing green manures and the exchange of land parcels should make organic tillage more attractive.

6. Organic cereal prices are currently strong across Europe and should help maintain good margins.

7. The entire organic sector in Ireland needs a substantial increase in the organic tillage area if it is to thrive and reach its potential.

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Coping with Nitrates and Cross Compliance Regulations in Tillage

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SUMMARY

Environmental protection laws e.g. the Nitrates Directive, are a now a reality of modern tillage farming. Rules concerning maximum fertilizer limits, fertilizer spreading and stubble management will force tillage farmers to change the way they fertilize crops and manage stubble land over the winter. Farm records will have to be kept to support fertilizer purchases and cereal yields. Farmers found in breach of the laws may incur a statutory penalty (up to €3000) and put their Single Farm Payment at risk. In the future growers will need to be much more discerning about the timing and rates of fertilizer applications as the maximum fertilizer limits cannot be exceeded. The Nitrates Directive is a serious challenge both to farmers and their advisors; however we are confident that there is enough flexibility in the regulations to allow profitable crops to be grown in the future. Teagasc advisors have the necessary knowledge and computer software to help farmers comply with the Nitrates Directive.

INTRODUCTION

The Single Farm Payment (SFP) scheme became law in Ireland on Jan 1st 2005. Under the SFP, farmers are required to respect the Statutory Management Requirements (SMRs) set down in EU legislation on the environment; public, animal and plant health; and animal welfare. Growers must also maintain land in Good Agricultural and Environmental Condition (GAEC). These combined regulations are known as Cross-Compliance. In all there are 19 SMRs of which two will be covered in this paper which are of importance to tillage farmers, SMR 4 (Nitrates regulations), SMR 9 (Plant protection products regulations). SMR 11 (Food safety regulations) also applies to tillage farmers as primary food producers. The remaining SMRs only become relevant to a farm if the system of farming includes livestock.

STATUTORY MANAGEMENT REQUIREMENTS

Nitrates regulations (SMR 4)

The Minister of the Environment, Dick Roche, T.D. signed into law, Statutory Instrument (S.I.) 378 on 1st August 2006. This legislation has become known as 'the Nitrates Directive' and was the cause of much debate and controversy since its inception. However, SI 378 of 2006 is now a law of the land that applies to everyone and carries penalties if not obeyed. SI 378 has its foundations in EU directive 91/676/EEC which deals with the protection of waters from pollution caused by nitrates from agricultural sources. The directive has three main pillars under which the aim of reducing water pollution from agricultural sources is addressed:

1. Farmyard management (incl. slurry storage, soiled water etc.)
2. Nutrient management (incl. crop & grassland fertilizer limits etc.)
3. Prevention of water pollution from fertilizers and certain activities (incl. ploughing & total herbicide rules etc.)

Farmyard management

For tillage farmers with no livestock this section has little relevance. Washings from vegetables and from farm machinery are considered to be soiled water. This soiled water has to be contained for 10 days within the closed period (see appendix 1 & 2) and land-spread in the correct manner.

Nutrient management

Effective nutrient management is a commonsense and economic approach to farming. Nutrients are becoming increasingly expensive as raw materials and energy costs rise and the misuse of nutrients has environmental consequences. The vast majority of farmers have been using nutrient management techniques successfully for years; however, previous fertilizer guidelines are now legal maxima.

Organic nitrogen – 'the 170 kg/ha limit'

Each livestock farmer has received a statement of their organic nitrogen from the Dept of Agriculture, Food & Forestry (DAFF). Organic nitrogen is determined by the stocking rate of animals on a farm and quantities of organic manures imported onto a farm. The maximum permitted limit is 170 kg organic N/ha. On livestock farms it is effectively a stocking rate limit. It is not a limit on chemical N fertilizer. A livestock farmer must apply to the DAFF for a derogation to farm above this level, but only up to 250 kgs organic N/ha (the full details on the derogation process have yet to be announced by the DAFF). Tillage farmers importing organic manures are limited to 170 kg organic N/ha. For example you are limited to spreading 15.5t /ha of broiler litter per year (see appendix 4).

Crop fertilizers

SI 378 strives to ensure that the crop's requirement for nutrients are satisfied. The fertilizer levels in the directive are maximum permitted levels and not recommended rates for a given set of circumstances. You are not obliged to spread the levels outlined in the directive. REPS farmers are obliged to follow their plans for fertilizer advice.

SI 378 uses four criteria to determine what chemical fertilizer a crop requires:

Soil phosphorus index

The phosphorus (P) advice for cereal crops is shown in appendix 3. No chemical fertilizer P is permitted at soil P index 4 unless potatos or beet are being grown. Soil analysis is the basis to determine the crops P requirement. In the absence of a soil test taken in the last 5 years, soil P is assumed to be at soil P index 3.

Potash (K) is not included under SI 378 but should be part of any nutrient plan.

Soil nitrogen index

The soil nitrogen (N) index system indicates the soils ability to supply N during the growing season and depends on the previous cropping history and previous organic manure applications. There are four N indices ranging from 1 to 4 - index 1 soils containing small soil nitrogen reserves and index 4 soils having the largest soil nitrogen reserves. Within SI 378 the nitrogen index table is split into two (see appendix 5). The upper half of the table applies to tillage crops grown in land more than 5 years 'away' from long term grass leys and is the most common situation found on farms. The lower half of the table applies to tillage crops grown in land less than 5 years 'away' from long term grass leys. In appendix 5, the crop within the columns is the previous crop. For example, in the case of land being in tillage more than 5 years, where oilseed rape was the previous crop, the soil is classed as being in N index 2.

Previous cereal crop yields

Additional nitrogen is allowable under SI 378 for high yielding cereal crops. The higher yield is based on the best yield in any one of the three previous harvests at 20% moisture content. For every 1 tonne/ha above reference yields (see appendix 6), a farmer may apply an extra 20 kg N/ha. Records (weighbridge dockets, etc) should be used to support farm reference yields. For example, a farmer averaged 11 t/ha (@ 20 % mc) for winter wheat in 2006. This is 2t/ha more than the reference yield. Therefore he is allowed to spread the standard 190 kg/ha + 40kg/ha for extra yield giving a total of 230 kg N/ha for 2007-2009 on his winter wheat crops.

Organic manures

The nutrient value (N & P) of all organic manures is specified in SI 378. The phosphorus contained in organic manures is deemed to be 100% available to the crop. The nitrogen in organic manures has varying rates of availability, increasing up to 2010 in order to encourage better and novel use of manures. If land has received dressings of organic manure in two successive years, it is deemed to be soil N index 2. Transitional provisions allow that imported pig, poultry and spent mushroom compost can be applied to P index 4 soils up until 2011. However, the 170 kg organic N/ha limit still applies and all the imported phosphorous is assessed on a whole farm basis.

Prevention of water pollution from fertilizers and certain activities

Application of fertilizers

There is a detailed section in SI 378 on the best practice methods of applying chemical and organic fertilizers. These are already being implemented by farmers under the 'Code of Good Farming Practice' with some additional measures. In general these rules detail how close you can spread organic and chemical fertilizers to watercourses and drinking water abstraction points. The amounts and the permitted spreading times of organic and chemical fertilizers are outlined also. A major change from the 'Code of Good Farming Practice' is that the country is now divided into 3 distinct zones each with its own set of dates during which it is prohibited to spread organic and chemical fertilizers. These zones, and the periods during which you cannot spread fertilizers, are set out in appendices 1 & 2.

Ploughing (incl. min-till)

There is much research to show that arable ground left 'bare' over winter is at more risk of nitrogen leaching than ground with a sown crop and it seems plausible that any practice that reduces soil nitrogen leaching will benefit the following crop. Under SI 378, autumn ploughing (1st July – 15th Jan) of arable land is only permitted if the following crop is emerged within 6 weeks after ploughing. With winter crops this is usually the case, but for spring crops, the practice of autumn ploughing and leaving the soil 'bare' over the winter is no longer possible. Grassland (incl. set-aside under grass) cannot be ploughed between 16 October and the 30th of November. Grassland can be ploughed after this date and crops can be sown at the grower's convenience.

Use of total herbicides (e.g. glyphosate)

If you spray a total herbicide between the 1st July and 15th Jan, you must have a green cover emerged within 6 weeks after spraying. This may be from a sown crop or natural regeneration. In practice, natural regeneration occurs after a pre-harvest application of glyphosate, but a post-harvest application will prevent natural regeneration. Note that in the case of maize and root crops (potatoes, beet & vegetables) no action is required to establish a green cover over-winter.

Plant protection products regulations (SMR 9)

These regulations apply to all farmers using plant protection and biocidal products. The farmer requirements are summarised as follows:

Use of pesticides

Only use and keep in store, pesticides that are authorized by the Pesticide Control Service (PCS). The full list is published each year by the PCS and available from their website www.pcs.gov.ie . Pesticides should be used and handled in accordance with current labels.

Records of pesticides

Keep a record of pesticide application date, rate and quantity. The Irish Grain Assurance Scheme (IGAS) record book and the Teagasc E-crops program are acceptable for this purpose. Keep a record of the PCS registration number of any pesticides used.

Pesticide store

Ensure the pesticide store is leak-proof and have a bucket of sand available to soak small spillages. Keep pesticides in a signed, secure shed/press etc. Dispose of empty pesticide cans to an authorized body – keeping the disposal receipt.

PRACTICAL WORKINGS OF NITRATES DIRECTIVE

Case study A

Farm "A" is an all tillage farm in Munster. All crop land is owned (160 Ha) and set-aside is rented (20 Ha). The farm is run as a one person operation with casual labour at harvest time. All grain is dried on farm and sold ex-store. The original crop rotation comprised of sugar beet, winter wheat and winter barley. Since 2006 winter oats has been substituted for sugar beet with increasing areas of continuous wheat and barley. All set-aside is under permanent pasture. In table 1 crop, yield and nitrogen use in the 2006 crop year are given. Farm records also show that a total of 4910kg of phosphorus was spread in 2006.

Table 1: Average farm yields and nitrogen applications for Farm A in 2006

Crop	**Avg. yield (t/ha)**	**Avg. Nitrogen (kg/ ha)** A	**Area (ha)** B	**Total Nitrogen 2006 (kgs) A x B = C**
Winter Wheat	9.2	210	70	14700
Winter Barley	7.4	180	70	11900
Winter Oats	(7.5)*	150	20	3000
Set-aside	N/A	50	20	1000
		Totals	**180**	**30,600**

* Yield for 2006 only.

For 2007, to comply with SI 378 a stepwise approach was adopted to determine what chemical fertiliser he can apply in 2007.

Step 1: Calculate the maximum allowable nitrogen fertilizer based on planned crop program, previous cropping history and cereal yields (Table 2).
Step 2: Calculate the maximum allowable phosphorus fertilizer based on soil analysis or assume soil P index 3 if no soil analysis is available (Table 3).
Step 3: Calculate the nutrient content of any organic manure imported onto the farm and subtract from the maximum allowable amounts to determine the allowable chemical fertilizer.
Step 4: Apply fertilizers (chemical & organic) in accordance with the regulations.

Table 2: Determining 2007 nitrogen allowances for Farm A

Previous Crop (2006)	Current Crop (2007)	Base Nitrogen allowance (kg/ha) A	Additional Nitrogen allowance (kg/ ha) B	Total Nitrogen allowance (kg/ha) A+B=C	Area (ha) D	Total Nitrogen (kgs) C x D=E
W. Oats	W. Wheat	190	30	220	70	15400
W. Wheat	W. Barley	160	10	170	70	11900
W. Wheat	W. Oats	145	0	145	20	2900
Set-aside	Set-aside	125	0	125	20	2500
				Totals	**180**	**32,700**

Notes:

- Previous high whole-farm yields: W. Wheat 10.5 t/ha (2004); W. Barley 9.0 t/ha (2006) were available to calculate additional Nitrogen allowance
- Set-aside is allowed 125kg N /ha as it is under grass (Table 14 of SI 378).

Table 3: Determining 2007 phosphorous allowance for Farm A

Crop	Soil Phosphorus Index	Phosphorus allowance (kg/ ha) A	Area (ha) B	Total Phosphorus Kgs A x B = C
Winter Wheat	1	45	70	3150
Winter Barley	2	35	70	2450
Winter Oats	3	25	20	500
Set-aside	N/A	20	20	400
		Totals	**180**	**6500**

- Set aside is allowed 20 kg P/ha (Table 15 of SI 378).

In 2006 farmer A applied 30,600 kgs nitrogen over all crops. Under SI 378 he is allowed to spread 32,700 kgs nitrogen over all crops. Farmer A is satisfied that the levels of nitrogen applied in 2006 grew very profitable crops on his farm. Farmer A may not require all of the maximum nitrogen allowance in 2007.

Case study B

Farm B is an all tillage farm (200 ha) also in Munster. Half the land is leased (100 ha). The farm is run as a one person operation with casual labour and some family labour at sowing and harvest time. All grain is sold off the combine incl. some farm to farm sales. The farm tries to maximize the area of 1st wheat using beans, rape and oats as break crops. The set-aside is under permanent pasture and energy crops (rape). Some poultry manure is planned to be imported for 2007 from a local poultry producer.

The total farm chemical nitrogen and phosphorus used in 2006 was 27,800 kgs and 7100 kgs respectively (from farm records). A stepwise process was also used with Farmer B to determine his total farm fertilizer allowance for 2007. The nitrogen allowances are shown in Table 4.

Table 4: Determining 2007 nitrogen allowances for Farm B

Previous Crop (2006)	**Current Crop (2007)**	**Base Nitrogen allowance (kg/ha)**	**Additional Nitrogen allowance (kg/ ha)**	**Total Nitrogen allowance (kg/ha)**	**Area (ha)**	**Total Nitrogen (kgs)**
		A	**B**	**A+B=C**	**D**	**C x D=E**
Beans	W. Wheat	140	50	190	30	5700
Rape	W. Wheat	140	50	190	20	3800
W. Oats	W. Wheat	190	50	240	50	12000
W. Wheat	W. Oats	145	30	175	20	3500
S. Barley	Rape	225	0	225	30	6750
S. Barley	Beans	0	0	0	40	0
Set-aside	Set-aside	125	0	125	4	500
				Totals	194	32250

Notes:

- Previous high yields: W. Wheat 11.5 t/ha; W. Oats 9.0 t/ha; S. Barley 8.0 t/ha
- The total amount of phosphorus allowance for 2007 is 6850 kgs based on soil analysis and appendix 4
- Following a break crop, the soil is deemed N index 2 for the subsequent crop.

Organic manures

Farmer B intends to apply 60 tonnes of broiler litter onto stubble ground in Feb 2007. He intends to plough it as soon as possible after application and sow a spring crop. Nutrient calculation for organic manures and its implication for total chemical fertilizer allowance are given in tables 5 and 6 respectively.

Table 5: Nutrient calculation for organic manures

Manure type	Quantity (t) A	Total Nitrogen (kg/t) B	Availability % C	Available Nitrogen (kgs) A x B x C = D	Total Phosphorus (kg/t) E	Available Phosphorus (kgs) A x E = F
Broiler Litter	60	11	35	231	6	360

Farmer B will alternate poultry manure spread-areas around the farm, to ensure that each plot gets a maximum of one application every two years, to remain in soil N index 1.

Poultry manure (& pig manure) contains high proportions of ammonia nitrogen which is readily available to the crop but also easily lost to the environment. In order to achieve the full benefit from poultry manure it should be incorporated as soon as possible (<24 hours) after application and used for spring crops. This strategy ensures that the crop demand for nitrogen is sufficient to take up the nitrogen in the manure, before it can be volatilized or leached. If it is applied in the autumn, crop demand is not sufficient to take up the nitrogen, putting it at increased risk of being lost over the winter period.

Table 6: Determining total chemical fertilizer allowance for 2007

	Nitrogen (kgs)	Phosphorus (kgs)
Total Farm Allowance (from Table 4)	32250	6850
Available Nutrients in manure (from Table 5)	231	360
Total Farm Chemical Allowance	32019	6490

By using the high yields achieved in 2004 and 2006, farmer B will also have a sufficient total farm fertilizer allowance to meet his requirements and continue to grow profitable crops into the future. The crop rotation is changing from 2006 and the total nitrogen allowance is not comparable directly between the years. The poultry manure is valued at €14 per ton fertilizer (NPK) value (not incl. spreading charges). If profitable crops can be grown using poultry manure as part of the fertilizer strategy, farmer B intends to increase the amount imported onto the farm and save on his fertilizer bill.

On-farm strategies to comply with N directive & cross compliance

Fertilizer

- Calculate total farm fertilizer allowance. The DAFF will inspect fertilizer records on a total farm basis **not** on a field by field basis. It is up to each farmer to allocate fertilizer to achieve maximum economic return, with due regard to environmental protection.
- Use high cereal yields to spread additional nitrogen. Growers are allowed to choose the top yield from any one of the 3 previous harvests.
- Apply organic manures at a maximum of "once every two years" basis to individual plots to remain under Nitrogen Index 1.
- Apply and incorporate organic manures as near to crop growth as possible to derive maximum benefit from organic nitrogen, with regard to environmental protection.
- Soil sample plots regularly (1 in 5 years) to take account of soil Phosphrus changes and keep the soil sample records.
- Growers will need to be more discriminating concerning timing and conditions when applying fertilizers to ensure maximum effect.
- Possibly delay top dressing very early sown (before end Feb) spring crops until after mid March due to limitations in applying nitrogen above SI 378 rates.

Records

- Keep records of cereal yields at harvest time. The DAFF will request weighbridge dockets to verify farm yield for each cereal crop. If no records are available, you will have to keep to maximum limits (appendix 6).
- Keep records of fertilizer purchases e.g. dockets. Fertilizer spreading records are not necessary, unless you are in a derogation situation.
- Keep Pesticides records. The I.G.A.S book or other suitable record format is acceptable.
- Calculate farm fertilizer allowance.

Ploughing and use of total herbicides

- Identify and treat fields with perennial weed problems e.g. scutch, pre-harvest (excluding seed crops).
- Apply post-harvest total herbicide before early October. Use stubble cultivation to encourage natural regeneration.
- When excessive stubble growth occurs, stubble ground may be grazed (GAEC regulations still apply).

Teagasc response to the nitrates challenge

Advisory

The Nitrates Directive and Cross Compliance will be one of the main drivers in the Teagasc Advisory Program for 2007. It will be addressed as part of ongoing work (one to one consultations, discussion group meetings, seminars, media articles & internet pages) and through novel initiatives (workshops, computer spreadsheets etc). Advisory staff will have the necessary tools and knowledge to meet the needs of their clients regarding the Nitrates Directive.

Research

Many elements of the research programme deal with issue related to the current regulatory challenges. Nitrogen response trials and projects dealing with winter cover crops are continuing. Two major research projects are being carried out between Teagasc Research Centers to improve nutrient efficiency and lower ammonia emissions from animal manures. Teagasc Oak Park has started a five year project into improving the effectiveness of pig slurry onto cereal crops. Oak Park research staff will hold a major demonstration on current animal manure spreading technologies in early March 2007.

CONCLUSIONS

- Cross compliance and the Nitrates Directive will be a serious challenge to all farmers, including tillage farmers. Failure to comply with the regulations will mean deductions from the SFP and loss of income.
- For tillage farmers, the main issue will be the nutrient management element of the directive, however the majority of tillage farmers will be able to continue to grow profitable crops and comply with the directive.
- Growers will need to be more discerning about timing and rates of N & P applications than heretofore and will have to take cognisance of and minimise possible losses to the environment as the maximum fertilizer limits cannot be exceeded.
- Organic manures must be treated as a valuable source of nutrients. New thinking and novel technologies will be needed when applying organic manures to crops in order to get the maximum benefit from them.
- Growers will have to have a planned approach to perennial weed control post harvest.
- Growers will have to maintain the necessary records for fertilizers, pesticides and cereal yields.
- Teagasc research and advice will ensure that growers can meet the challenges of the Nitrates and Cross Compliance regulations and continue to farm profitably. Teagasc has developed a software program to calculate the total farm fertilizer allowance and slurry storage on the farm.

Appendix 1: Country Zones

Zone:

A Carlow, Cork, Dublin, Kildare, Kilkenny, Laois, Offaly, Tipperary, Waterford, Wexford, Wicklow.

B Clare, Galway, Kerry, Limerick, Longford, Louth, Mayo, Meath, Roscommon, Sligo, Westmeath.

C Cavan, Donegal, Leitrim, Monaghan.

Appendix 2: Non-application periods of fertilizers to land

Fertilizer Type	Start date		End date			
		Zone	A	B	C	
Chemical	15th Sept.	to	12	15	31	Jan.
Organic (not FYM)	15th Oct.	to	12	15	31	Jan.
FYM	1st Nov.	to	12	15	31	Jan.

Appendix 3: Maximum fertilization rates of phosphorus on tillage crops (taken from SI 378)

Crop	Phosphorus Index 1	2	3	4
	Available Phosphorus (kg/ha)[1]			
Winter Wheat	45	35	25	0
Spring Wheat	45	35	25	0
Winter Barley	45	35	25	0
Spring Barley	45	35	25	0
Winter Oats	45	35	25	0
Spring Oats	45	35	25	0
Sugar Beet	70	55	40	20
Fodder Beet	70	55	40	20
Potatoes: Main crop	125	100	75	50
Potatoes: Early	125	115	100	50
Potatoes: Seed	125	115	100	85
Maize	70	50	40	0
Field Peas	40	25	20	0
Field Beans	50	40	20	0
Oil Seed Rape	35	30	20	0
Linseed	35	30	20	0
Swedes/Turnips	70	60	40	40
Kale	60	50	30	0
Forage Rape	40	30	20	0

[1] The fertilization rates for soils which have more than 20% organic matter shall not exceed the amounts permitted for Index 3 soils.

Appendix 4: Amount of nutrients contained in 1 tonne of organic fertilizers other than slurry (taken from SI 378)

Livestock type		Total Nitrogen (kg)	Total Phosphorus (kg)
Poultry manure	broilers/deep litter	11.0	6.0
	layers 55% dry matter	23.0	5.5
	Turkeys	28.0	13.8
Dungstead manure (cattle)		3.5	0.9
Farmyard manure		4.5	1.2
Spent mushroom compost		8.0	2.5
Sewage sludge		Total nitrogen & total phosphorus content per tonne shall be as declared by the supplier in accordance with the Waste Management (Use of Sewage Sludge in Agriculture) Regulations, 1998 to 2001 and any subsequent amendments thereto.	
Dairy processing residues and other products not listed above		Total nitrogen & total phosphorus content per tonne based on certified analysis shall be provided by the supplier	

Appendix 5: Determining nitrogen index for tillage crops (taken from SI 378)

Continuous tillage: - crops that follow short leys (1-4 years) or tillage crops			
	Nitrogen index		
Index 1	**Index 2**	**Index 3**	**Index 4**
Cereals Maize	Sugar beet Fodder beet Potatoes Mangels Kale Oil Seed Rape Peas, Beans Leys (1-4 years) grazed or cut and grazed.		
	Swedes removed	Swedes grazed in situ	
	Any crop receiving dressings of organic fertiliser		
Vegetables receiving less than 200 kg/ha nitrogen	Vegetables receiving more than 200 kg/ha nitrogen		
Tillage crops that follow permanent pasture			
Index 1	**Index 2**	**Index 3**	**Index 4**
Any crop sown as the 5th or subsequent tillage crop following permanent pasture	Any crop sown as the 3rd or 4th tillage crop following permanent pasture. If original permanent pasture was cut only, use index 1	Any crop sown as the 1st or 2nd tillage crop following permanent pasture (see also Index 4). If original permanent pasture was cut only, use index 2	Any crop sown as the 1st or 2nd tillage crop following very good permanent pasture which was grazed only

Appendix 6: Maximum fertilization rates of nitrogen on tillage crops (taken from SI 378)

Crop	Nitrogen index 1	2	3	4
	Available nitrogen (kg/ha)			
Winter Wheat[1]	190	140	100	60
Spring Wheat[1, 2]	140	110	75	40
Winter Barley[1]	160	135	100	60
Spring Barley[1]	135	100	75	40
Winter Oats[1]	145	120	85	45
Spring Oats[1]	110	90	60	30
Sugar Beet	195	155	120	80
Fodder Beet	195	155	120	80
Potatoes: Main crop	170	145	120	95
Potatoes: Early	155	130	105	80
Potatoes: Seed	155	130	105	80
Maize	180	140	110	75
Field Peas/Beans	0	0	0	0
Oilseed Rape	225	180	160	140
Linseed	75	50	35	20
Swedes/Turnips	90	70	40	20
Kale	150	130	100	70
Forage Rape	130	120	110	90

[1] Where proof of higher yields is available, an additional 20kg N/ha may be applied for each additional tonne above the following yields;

Winter Wheat - 9.0 tonnes/ha   Spring Wheat - 7.5 tonnes/ha
Winter Barley - 8.5 tonnes/ha   Spring Barley - 7.5 tonnes/ha
Winter Oats – 7.5 tonnes/ha   Spring Oats – 6.5 tonnes/ha

The higher yields shall be based on the best yield achieved in any of the three previous harvests, at 20% moisture content.

[2] Where milling wheat is grown under a contract to a purchaser of milling wheat an extra 30 kg N/ha may be applied.