National Tillage Conference 2003

Conference Papers

Trends and Outlook in EU and World Cereal Markets

Gerald Mason
Senior Economist
HGCA, UK

SUMMARY

Changes in EU agricultural policy, re-emergence of FSU producers and currency have all been well documented as important factors bringing the EU into line with world markets. Coincidentally, this process has happened at the same time as a major natural check on production in North America and the Southern Hemisphere this season. This paper explores why EU grain prices seem not to have benefited from the check this season. It also goes on to highlight the key issues that could drive wheat and barley markets in the 2003/04 season. In particular, it highlights how, with low world wheat and feedgrain stocks, prices next season will be particularly dependent on weather in major producing regions in coming months.

SO WORLD MARKETS ARE HERE TO STAY?

After a period of adjustment and transition over the last three years, world market prices now clearly drive EU cereal prices. Lower EU intervention support prices, together with a relatively weak Euro versus the dollar (albeit stronger recently), mean that daily movements in world prices are now impacting on EU prices. Notwithstanding a major appreciation in the value of the Euro, or a sharp drop in world dollar prices of grain, it is difficult to envisage a scenario where this will not continue to be the case.

BUT WHAT IS THE WORLD PRICE?

It is certainly fair to ask how the world market price is now denominated. Previously, US prices drove world wheat markets whilst EU prices often drove world barley prices. The emergence of the Ukraine and Russia as major exporters in the last two seasons has, however, fragmented the world market. At present, US prices are well above other origins driven by tight supply. Meanwhile, FSU prices remain at a discount to almost all other origins of grain due to high supply.

Defining world price thus now depends on the exact quality of grain you are discussing. Once established, probably the best definition of world price in the future will be "that which is most competitive at any point in time with other grains of the same quality". The world price could possibly vary between supplier not just by season, but even within season.

WHAT IS HAPPENING IN THE MARKET AT THE MOMENT?

2002/03 is certainly the most interesting situation since the major rally in the mid-90s and probably since the major upheavals in world grain markets in the mid-70s. Most commercial people making decisions in the grain market agree that it is very difficult to call price direction this season. A combination of weather, political and currency issues – all unpredictable – are the key reasons why.

Weather issues have featured in North America and the Southern Hemisphere, sharply reducing supply of quality wheat, barley and oats. In contrast, EU and FSU harvests have been very good.

Politics continues to present uncertainty in the EU market in particular. A clear political will to reform the system that provides protection for EU grain markets against non-EU imports has been present since the end of 2001/02. The practicalities of when and how any new system will actually impact on EU markets are only likely to be seen in coming months.

And the recent weakness of the dollar against the euro, after a period of relative stability, is a reminder that currency markets can be unpredictable and important for EU grain prices competing in world dollar-denominated markets.

Tell Us More About the World Wheat Market in 2002/03

The world wheat market is split very clearly into two this season. Supplies of high quality wheat in North America and Australia have been hit by low initial plantings followed by a prolonged drought. Compounding the problems has been wet weather in Canada during harvest, harming quality. This has lead to a sharp rise in quality wheat prices. They rose around $80 per tonne between July and November, before falling back a little recently.

In contrast, supplies of soft wheat and feed wheat are much more plentiful. The EU soft wheat harvest is up 10M tonnes on last season, and both the Ukraine and Russia have had a second very good harvest. At this end of the market, prices have risen by a modest $10 to $20 per tonne since July.

Compounding the uncertainty in the EU has been the proposal to change the import duty system to offer more protection from FSU imports. Ukranian and Russian feed wheat have been imported in big volumes, often at prices as low as $90 to $100 delivered to southern-EU consumers. This has lead to import licences for wheat rising to a dramatic 8.9M tonnes in the first six months of the season, compared to a normal 1.2M tonnes at this point in previous years. The new TRQ system limits low and medium quality wheat imports to around 3M tonnes per year. However, its full impact may not be seen until March 2003 onwards as many of the import licences granted under the old system are still valid in the first 6 weeks of 2003.

The US corn crop also looks set not to provide the possible relief from low FSU prices that it could have, Drought in many parts of the US corn belt has reduced crop size to 229M tonnes, versus a normal 250M. However, traders think this can be offset by reducing US corn stocks, Chinese maize exports and feed wheat exports from the FSU, EU and India. With harvest now near-complete it is evident that the crop is no lower than these already low expectations. If it had been worse, it may have been difficult to make up the shortfall with the above.

In conclusion, high quality wheat markets look more robust, supported by tight supply at least until the 2003 US crop is harvested in June next year. At the soft and feed end of the wheat market the outlook is less certain. With the US corn crop out of the way, key wild-cards now include Ukrainan and Russian supply and how the new TRQ will impact on trade flows.

What About the Wheat Outlook for 2003/04?

In theory, the 2003 world wheat harvest should see production rebound from the low 562M tonnes in 2002. The first IGC estimate for 2003 puts the crop returning to 597M tonnes, similar to current consumption levels.

The main increases in output are expected in the high quality wheat producing regions of the US, Canada and Australia. The expectation is that current high prices in these regions will prompt farmers to expand area and, with a return to more normal yields, output is expected to rise 36M tonnes in these 3 countries alone.

However, the crop is still far from being secure. In the US, the first USDA estimate of winter wheat plantings for 2003 put area only 6% up on last season. Early trade estimates were for area to increase by 10% to 15%. However, the condition of the crop entering dormancy was much better this season.

Meanwhile, in Australia and Canada the crop is still four to six months from even being planted. In Canada, two seasons of drought have severely cut soil moisture levels on the prairies. Whether these can recover before planting in May is debatable. Australia also has very low moisture reserves, although recent rains show some signs of this improving.

In the FSU, meanwhile, planted area is down on last year. In Russia, winter grain plantings are down 2M ha, at 14M ha. Wet weather in some regions prevented farmers from planting. Whether this can be made up with spring plantings depends on weather in coming months. In the Ukraine, wheat plantings were down around 4%. More recently, a cold snap is thought to have left around 1.2M ha needing re-sowing in the spring compared to just 0.5M ha that have needed re-sowing in the last two seasons.

So, all in all, the early IGC estimate of 597M tonnes looks some way from being secure. Weather in the US as the winter crop exits dormancy and the spring crop is planted will be key. Rain is needed in Canada and Australia to replenish soil moisture levels in order to get to expected output levels. Whilst, in the FSU, wet and cold weather alternately are leaving more reliance on spring plantings in Russia and the Ukraine. Just as a reminder, the initial estimate of the 2002 world crop was coincidentally 597M tonnes. It is currently estimated to be 562M.

I Keep Hearing About the US Maize Crop. Why is This Important?

The US maize crop is the single biggest grain crop in the world. It accounts for around 30% of world feedgrain production and 70% of world trade in feedgrains. The world’s reliance on it is huge.

It is planted on 14M hectares, 48 times the area of the Irish wheat and barley area combined. Historically, yields can vary considerably, particularly when drought hits the Midwest maize belt. However, harvest 1997 through to 2001 were all uneventful, with yields very close to average. Harvest 2002 was different. Yield was around ¾ of a tonne below average, meaning around 22M tonnes of maize production was lost. This is forecast to lead to US maize end-stocks dropping by 17M tonnes this season to just 24M tonnes. This does not leave room for another crop problem next season to be absorbed by stock run-down.

This means that world feedgrain prices, and hence EU wheat and barley prices, will be particularly sensitive to the fortunes of the US maize crop this year. Planting starts in mid-April, and the critical yield-building period is through July and August.

What is Happening in the World Barley Market?

World barley markets have been affected by the same problems in the wheat market, and to a greater extent. Although EU barley production is similar to last season, at around 48M tonnes, production in other major exporters is sharply lower.

World barley production this season has fallen from 140M tonnes to 132M tonnes. More importantly, 7M tonnes of this drop is in the key malting barley suppliers of Canada and Australia. Canadian barley output is seen at just 7.5M tonnes, 3M tonnes lower than last season and 6M tonnes lower than usual. Australian barley output is seen at just 3.5M tonnes, down sharply on 7.5M tonnes last season.

With production significantly lower in tow of the three major malting barley suppliers, malting barley prices are significantly higher. EU prices are up around 70%, whilst in some consuming countries prices are nearly 100% higher. Of course, maltsters are varying the specification of barley to enable as much supply as possible. But, until the 2003 EU barley harvest, there is no new physical supply.

World feed barley markets have not risen as dramatically, but prices are still around $20 higher on July. In particular, FSU feed barley prices are not as aggressively prices compared to the EU as in the wheat market. The outlook for prices will depend largely on the EU export programme, the timing of sales from the FSU and purchases by major buyers in North Africa and the Middle East.

What About the Barley Outlook for 2003/04?

Once again, everything depends on the weather. In the EU, plantings are expected to be similar to last year. At the feed end of the market, particularly important will be the US maize crop, as a competing feedgrain, as we have just discussed. Also important will be how the crop develops in the Ukraine, where much of it is used and sold as feed. The cold snap has also damaged winter barley, so spring plantings will be important.

At the malting end of the market, weather will be the key price driver. The next malting barley harvest anywhere in the world is in the EU in August 2003. To get there, consumers are expected to run-down global malting barley stocks to very low levels. Whilst high prices should in principle encourage increased plantings, weather in Australia and Canada is still far from returning to normal. This will make weather conditions for the EU crop important and for the Canadian and Australian crop critical.

CONCLUSION

This season has proven that world markets are no longer just of interest, but are now relevant price-drivers for us in the EU. With low stocks in both the wheat and feedgrain market at the end of the season, the 2003 crop size is critical. If everything goes to plan, production should increase sharply. But this is still far from certain. In the meantime increased price volatility, in response to weather in particular, is certain.

Coping with the Price Cost Squeeze*

J. O'Mahony, Chief Tillage Adviser,
Teagasc
Crops Research Centre, Oak Park

SUMMARY

Tillage is an important industry providing employment for in excess of 20,000 people in the food processing and service sector in addition to the 16,000 growers. It occupies 9% of the total area farmed and contributed €405 m to Gross Agricultural Output.

Cereal prices dropped by 30% since 1995. Fertilisers and energy prices have increased by 17% and 23% respectively since 1999 having remained stable since 1990. Plant protection products have increased steadily by 1.5% per annum approximately. The cost of labour and insurance have increased dramatically in recent years.

The decline in the number of cereal growers and increase in scale is likely to continue and will be intensified due to pressure from the price cost squeeze.

The main avenues to improved profitability are increased scale and improved efficiency. The importance of financial analysis for both whole farm and crop/field performance is emphasised. Standing still is not an option. A radical assessment of scale and overhead cost (land, labour and machinery) will be rewarding in some situations. Registering for VAT is likely to be worthwhile on mainly tillage farms.

Data from trials at Oak Park and the Teagasc Farm Management Survey confirm that there is major scope for improved field performance. Growers will have to farm on a field by field basis, critically evaluating the return from all inputs.

Teagasc advisers are putting a renewed emphasis on financial analysis and planning. Start with an analysis of the present farm production system and financial returns. The e-Profit Monitor is the tool for this and is available to clients free on www.client.teagasc.ie. In addition to providing financial and technical advice, Teagasc advisors are now running short financial courses countrywide.

*The author wishes to acknowledge the assistance of Tillage Specialists Michael Hennessy and Derek O'Donoghue as well as the Financial Management Specialists in preparing this paper. The assistance of the research staff at Oak Park is also acknowledged.

INTRODUCTION

The tillage industry makes a valuable contribution to the economy. Tillage crops occupy 9% of the total area farmed in Ireland and account for over 7%, €405 million of Gross Agricultural Output.

The importance of the tillage sector is underlined by the fact that 40% of the 47,500 jobs in the food-processing sector are derived from tillage crops. Bread and flour confectionery accounts for 5,500 jobs, grain milling and animal feeds account for 2,800 jobs, the sugar sector accounts for 4,300 jobs with a further 6,100 people working in the drinks sector.

In this paper I will

- Examine the trends in product and input prices as well as the structure of the tillage industry

- Investigate avenues to improved farm profitability:

    - on a whole farm basis
    - on a field by field and input by input basis

- Draw conclusions

THE PRICE COST SQUEEZE

In order to establish future prospects in tillage, we need to look at the production, market and financial trends in the sector.

Data from CSO in Figure 1 shows that cereal prices dropped by 30% since 1995, having remained reasonably stable in the early 1990s. Prices dropped in 1994 following the introduction of area aid in 1993 but recovered in 1995. Fertilisers and energy prices have increased by 17% and 23% respectively since 1999 having remained stable since 1990. Plant protection products have increased steadily by 1.5% approximately per annum. The cost of overheads such as labour and insurance have increased dramatically in recent years.

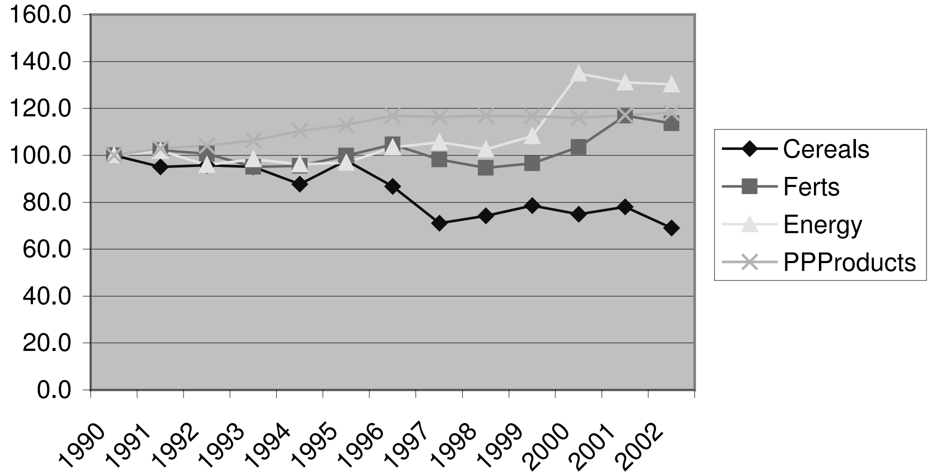

Fig. 1: Trends in cereals and inputs prices 1990-2002. (Re-based by 1990 = 100 Source: CSO)

The number of cereal growers has declined from almost 100,000 in 1975 to upwards of 15,000 in 2001 (Table 1). The biggest fallout has occurred amongst the smaller producers with a drop of over 90,000 in those with less than 10 ha.

Table 1: Number of cereal growers categorised by area grown

	<10 ha	> 50 ha	Total
1975	91,500	100	98,900
1985	41,100	400	50,000
1995	10,793	964	18,141
2000	831	1,105	14,791
2001*	-	1,469	15,428

*Department of Agriculture Area Aid Unit – Area Aid claimants
Source: Central Statistics Office

In parallel to this decline there has been a modest increase in the number of growers over 50 ha with the numbers rising from 100 in 1975 to 1,105 in 2000. The average cereal area per grower has increased from 3.4 ha in 1975 to 18.9 ha in 2000. The trend to larger growers will continue because of low margins per hectare and efficiencies with labour and machinery. Pressure on margins from the price cost squeeze will intensify this trend. I reckon there will be 1000-1500 specialised full time tillage farmers with close on 200 ha each within a 10 year time frame. There will be a further 5-6,000 smaller part time operators combining tillage with off-farm work or as a secondary farm enterprise.

AVENUES TO IMPROVE FARM PROFITABILITY

The main avenues to improved profitability are increased scale or improved efficiency. I will concentrate on two aspects of efficiency.

A. Whole farm
B. Field by field and input by input analysis

Whole Farm Scenarios

Thorough farm analysis can only be completed when good farm records of physical and financial operations are available on the farm. The FREE *Teagasc Cost Control Planner* will track all the financial transactions for the different enterprises throughout the year. The *Cost Control Planner* will give a report that can then be analysed through the e-profit monitor. The **e-*Profit Monitor*** programme will break down each enterprise in terms of variable and fixed costs (see Appendix 1).

This provides the farmer with an accurate financial picture of the latest production year. An evaluation of these figures will highlight the strengths and weaknesses of the production system and of the farm as a whole. The ***e-profit monitor*** figures can also be compared to similar production systems around the county/country.

The ***e-profit monitor*** figures can then be used to construct a farm budget for the next year using the *Tillage Cost Control Planner.* These figures can also be used as a base to calculate net profit in the future if the farming system was changed (as used in the example below).

Study farm

I am going to look at four different scenarios on an actual 139 hectare (343 acres) mainly tillage farm with 23 ha devoted to a weanling to beef production system. This is a good tillage farm with medium textured free draining soil. Over 70% of the cereal area is spring sown and 8.5 hectares of sugar beet are grown. Labour consists of the owner plus the equivalent of 0.8 labour units hired. The farm would be regarded as somewhat over-mechanised with machinery being replaced on a regular basis. Larger machines were purchased with a view to contract work.

Evaluation process

First the data from the farm was analysed using the e-profit monitor programme. This indicated that fixed costs were very high compared to other farms in the region and that profitability of winter wheat was superior to spring cereals on this farm (see Appendix 1).

Secondly, four different scenarios (plans) were evaluated using the Finpack computer programme. This enabled the comparison of future prospective plans in 2006 to be evaluated to against continuing with the present set-up.

Table 2 outlines the crops grown as well as the production and financial performance of the farm in 2002. The Teagasc e-Profit Monitor was used to provide the analysis (see Appendix 1). Performance levels are very good considering the known problems of 2002. Net profit on 109.4 ha of tillage was €40,140, i.e. €367/ha (€149/ac).

Table 2: Study Farm Details 2002

	Ha	T/ha	Gross Margin (€/ha)	Net Profit (€/ha)
Winter Wheat	12.9	9.12	889	466
Spring Wheat	14.1	8.19	772	388
Spring Feeding Barley	17.4	8.43	877	128
Malt Barley	32.3	5.64	707	378
Winter Oats	12.1	8.74	946	403
Sugar Beet	8.5	44.76	1,315	810
Setaside	12.1	-	371	204
Total Tillage	109	-	(2.47 leased)	
Grassland	23.3			
Total Farmed	132.7			

Scenario 1: Outcome in 2006 if no change in area farmed or cropping plan is made in the present set-up other than normal improvements in yields.

Scenario 2: Outcome in 2006 where the machinery policy changes from spreading the extra machinery capacity from contracting to increasing scale through the rental of an extra 40 ha for a spring barley. No other machines were purchased.

Scenario 3 Outcome in 2006 where the machinery and labour costs are reduced. The associated machinery for crop establishment was sold and a contractor used to establish the crop instead. A full time labour unit will no longer be required but some seasonal labour is used at harvest. Area farmed is the same as in Scenario 2. There is a larger proportion of the area in winter cereals in this scenario.

Scenario 4: Outcome in 2006 where the machinery and labour costs are reduced. A more radical plan is adopted where all crops are established using Eco-tillage and a contractor is used to harvest crops. All existing establishment equipment was sold and replaced with the appropriately sized Eco-tillage equipment. The combine is also sold. A full-time labour unit will no longer be required but some seasonal labour is used at harvest. Area farmed and cropping regime is the same as in Scenario 3.

Assumptions:

1. Product prices in 2006 are similar to 2002.
2. Input prices increase in line with Teagasc – FAPRI predictions.
3. Yields increase by 1.5% per year in all scenarios.
4. Renting an extra 40 ha will not necessitate any increase investment in machinery or labour.
5. A reliable machinery contractor is available.
6. Eligible land is available for rent and land is of good quality and well maintained.

Table 3 compares the financial performance of the four different scenarios in 2006 with the outcome for 2002.

Table 3: Comparison of financial performance of four scenarios on a mainly tillage farm (132 ha) from 2002 to 2006

	2002	2006			
	Base Year	SI	S2	S3	S4
Scenario(s)		Continue as for present	Scale Rent 40 ha	Labour Contractor to establish	Eco-tillage contractor to harvest
Net Farm income (€)	43,416	36,777	42,326	60,470	66,296
Rates of return on farm assets (%)	2.5	2.1	2.5	3.6	3.9
Net worth change per year (€)	6,550	687	3,573	14,447	16,517
Effect of a 10% decrease in output of all enterprises on:					
a) Net farm income	25,923	18,854	20,377	37,896	43,722
b) Cash surplus or deficit	2,643	-3,169	-2,453	6,709	6,779
c) Net worth change per year	-2,546	-8,358	-7,642	2,709	4.779

Note: Finpack computer programme (University of Minnesota – Teagasc) used for analysis.

The key financial measures I will report on are:

(a) net farm profit
(b) rate of return on farm assets or return on investment (ROI)
(c) net worth change per year
(d) sensitivity analysis.

(a) **Net Farm Profit** represents the income earned from all farming operations during the year in question. It is the reward for the farmer's labour, management skills and on-farm investment.

(b) **Rate of return on farm assets** can be thought of as the average interest rate being earned on all investment on the farm.

(c) **A positive net worth change per year** is likely to be one of the major goals of most farm families.

The annual net worth change is calculated by adding any net non-farm income to the net farm income and subtracting family living, income tax and social security payments and the interest portion of any non-farm debt payments. Net worth change per year is the projected amount net worth will change in a typical year for each alternative plan. This includes net worth change only from farm profits and non-farm income. Asset value changes are not considered.

(d) Sensitivity Analysis

The sensitivity analysis shows the results for each alternative plan if long range production levels, price levels or a combination of the two results in income levels lower than planned. It is used to analyse the relative differences in financial risk inherent in the alternatives under consideration.

The effect of a decrease in production or price (or a combination of both) on the net farm income, the cash surplus or deficit, and the net worth change per year for each alternative is shown. On a whole farm basis the effect of a 10% decrease in production or price are given.

Discussion of scenario outcomes

Net farm income

Scenario 1: Continuing with the present set-up will result in net farm income dropping by €6,639 to €36,777 in 2006. This is a serious drop in income especially when one considers that the purchasing value of this sum will be much poorer in four years' time depending on the rate of inflation in the meantime.

Message – Standing still is not a realistic option

Scenario 2: Increasing scale by renting an extra 40 ha will improve net farm income by €5,550 over continuing with the present situation. However, this will be €1,000 less than the present income in 2002. This shows a return of €138/ha (€56/ac) on rented land where no further investment in machinery or labour are required. Conacre is costed at €383/ha (€155/ac). Cutting conacre cost by €100/ha (€40/ac) will increase net farm income by €4,000.

Message – Increasing scale only is not enough to maintain income. Conacre price has a major influence on net farm income

Scenario 3: Cutting labour costs by €20,000 and hiring a contractor to establish crops will substantially improve income by €23,693 compared to continuing with the present situation in 2006. The farmer retains control over the important operations such as spraying and harvesting but is dependent on a contractor to establish the crop.

Message – taking a closer look at labour requirements on the farm and use contractors can make big changes in net farm income. This suggests that there can be major benefits from machinery sharing arrangements.

Scenario 4: A more radical examination of labour, machinery and the production system such as changing to Eco-tillage and the use of a contractor for harvesting can give further efficiencies and substantially improve net farm income by €29,500 in 2006 compared to continuing as present. However, risk is increased as the grower has to cope with new technology, Eco-tillage and harvesting is done on contract.

Message – a radical examination of overhead costs such as labour and machinery as well as the production techniques can lead to a substantial improvement in net farm income. This scenario also suggests that there can be major benefits from machinery sharing arrangements.

Rate of return on farm assets
Scenario 4 followed by Scenario 3 will give the best rate of return.

Net worth change per year
It is obvious that Scenarios 4 and 3 will provide considerable capital for future investment but continuing as present will not.

Sensitivity analysis
This confirms that Scenarios 4 and 3 are the best options even if there is a 10% decrease in performance of all enterprises. This also highlights the disastrous effect on cash surplus/deficit and net worth change per year in Scenarios 1 and 2.

Other Whole Farm Efficiencies

Whether to register for VAT or not?
Growers registered for VAT can claim back VAT paid on all inputs including materials, machinery, contractors, etc. They have to make returns to the VAT office every two months. There is a considerable incentive for mainly tillage farmers to register for VAT. The saving could be of the order of €50-100/ha depending on crop mix, machinery purchase etc.

Sources of finance
There is a considerable variation between the lending institutions. Data from Teagasc Monitor farms indicates that rates can vary by up to 5% for similar type loans. The message is to shop around to get the best rates.

Efficiencies on Field by Field, Input by Input Basis

The substantial drop in grain prices in recent years necessitates a closer look at input costs. There is considerable scope to cut rates of seed, fertiliser and chemicals without unduly affecting yield.

Seed

There is potential to save 9-30% in cost of seed when sowing under good conditions.

Table 4: Cereal seed rate and potential savings

	Normal Practice (kg/ha)	Potential rate under good conditions (kg/ha)	Potential Saving (%)
Winter barley	170	155	9
Winter Wheat	180	110	31
Winter Oats	165	150	9
Spring Barley	155	125	19

Fertilisers

In the case of P, K and trace elements there is potential for major savings where soil levels are high. Fertilise crops on the basis of a soil test for each field. Follow Teagasc recommendations on soil N index.

Chemicals

An in-depth knowledge of crops, pests and pesticides together with good husbandry and timely applications of treatments will produce top yields of good quality while keeping the chemical costs down. In the case of herbicides select product and rate on the basis of weeds present or anticipated. Use growth regulators and insecticides only where essential. Fungicide strategy should be based on disease risk. Consider variety, location, product choice as well as rate and timing of application.

Table 5 indicates that there is huge range in material costs when crops are grown under precise management where inputs are used only if required on a field by field basis compared to a high insurance type of regime.

Table 5: Range in winter wheat material costs (€/ha)

	Teagasc[1]	Potential Range[2]	Monitor Farms 2001[3]	
Total	500	254.5-771	Mean	Range
Seed	63	50-90	71	47-116
P, K	70	0-95	176	69-242
N	121	77-136		
Herbicide	50	10-139	43	31-69
Fungicide	150	100-200	125	75-166
Insecticide	34	10-42		
PGR	12	7.5-49		

1 = Teagasc crop costs and returns 2003
2 = Lower range implies precise management of inputs. VAT is not applied as it is assumed VAT registered. Higher range implies insurance approach and VAT is applied to pesticides. The range varies from €254 (which is half the Teagasc figure) to €771/ha which is €270 more than the Teagasc figure.
3 = Data from Teagasc monitor farms confirms that there is a huge range in the level of costs associated with all inputs.

Machinery
An Oak Park Survey 1992-1994 identified a huge range in machinery cost ranging from €118/ha to 432/ha averaging €246/ha. Dermot Forristal, Teagasc, Oak Park has developed a very useful computer programme to help advisors and farmers rationalise their machinery strategy and costs.

Teagasc Oak Park Long-Term Trials on Reduced Inputs

Results from the last seven years show that a reduction in the use of ago-chemical inputs (pesticides and fertilisers) gave lower yields of winter cereals but increased profitability. However, in the case of spring malting barley reduced inputs gave lower profits.

This long-term experiment conducted by Dr. M. Conry and J. Hogan compares the effect of:

- A conventional high-input system with
- a reduced input system on the yield and quality of winter wheat and winter barley when grown:

  (a) In a five year break-crop rotation with spring barley
  (b) In a three year cereal rotation with winter oats and
  (c) in continuous monoculture

The cereal crops were grown under two input system: Conventional high-input system and reduced input system. The inputs in the conventional system were consistent with good farm practices carried out by the best cereal growers while the inputs in the reduced-input system were based on value judgement and certain principles. The reduced inputs system received:

1. 20% less N and no P because phosphate levels were high.
2. 50% of less pesticides (herbicides, insecticides and fungicides) than the high inputs system.
3. a reduction (up to 50%) in the amount of plant growth regulators.

Table 6 compares the gross margins for the different treatments.

Details of costs and yields can be seen in Appendix 3 and 4 respectively.

Table 6: Effect of conventional and reduced input systems on gross margins of cereals grown in different rotations

		Gross Margins (€./ha)	
Crop	**Treatments (Rotations)**	**Conventional**	**Reduced**
Winter Wheat	Break-up	774	887
	Rotation	828	917
	Continuous	727	817
	Mean	776	874
Winter Barley	Break Crop	684	736
	Continuous	672	690
	Mean	677	704
Winter Oats	Rotation	666	716
Spring Barley	Break Crop	785	753

Farm management survey (FMS)

Data from FMS for the five years 1997-2001 shows that there is scope for improved efficiency on some farms. The top 25% of grower's net margin per hectare is more than double the bottom 25% of growers despite little difference in total costs (see Figs. 2 and 3).

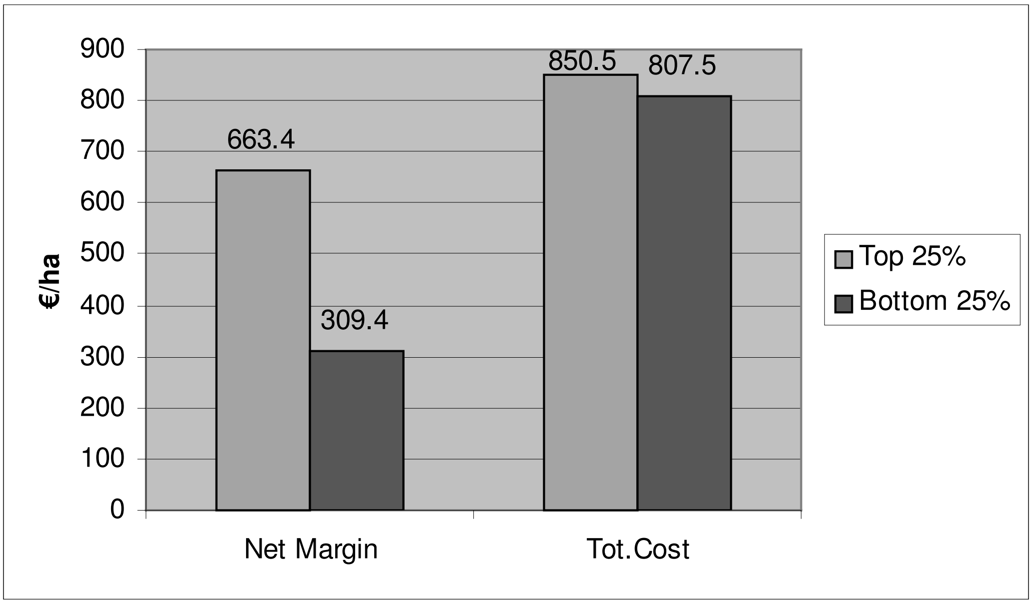

Fig 2: Winter wheat net margin excl. conacre and total cost €/ha (FMS 1997-2001)

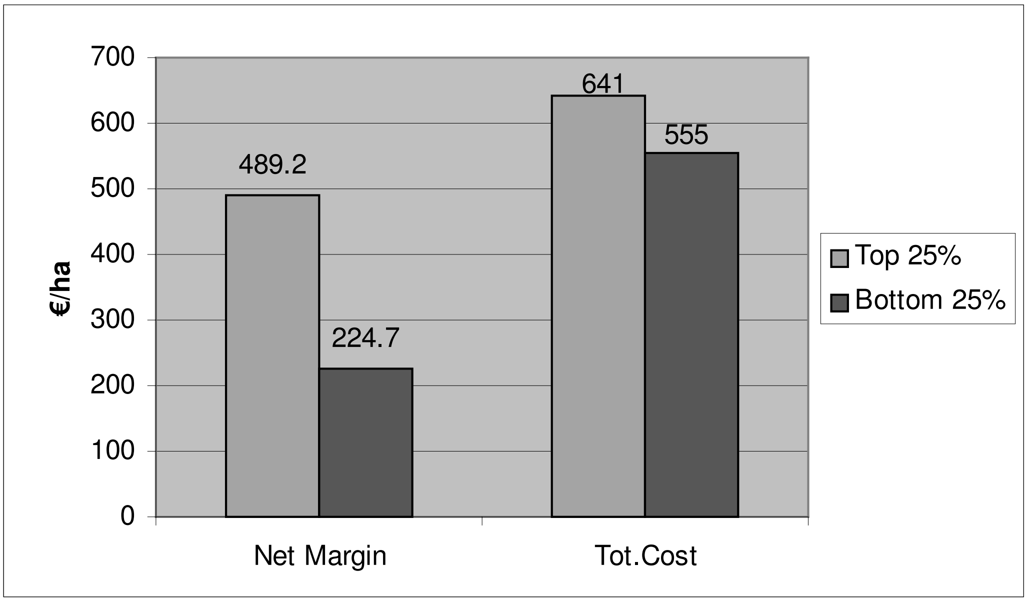

Fig. 3: Spring feed barley net margin excl. conacre and total cost €/ha (FMS 1997-2001)

CONCLUSIONS

The price cost squeeze will present a major challenge for tillage farmers over the next four years. However, growers can maintain or increase incomes by close financial management and improved technology. Standing still is not a realistic option. Avenues for improved margins include increased scale and close examination of overhead costs including land, labour and machinery. Increased use of contractors, machinery sharing arrangements, share farming and Eco-tillage will provide economies for some.

Data from trial work at Oak Park and the Farm management survey confirms that there is major scope for improved field performance. Growers will have to farm on a field by field basis, critically evaluating the return from all inputs.

There is huge scope for cutting costs with more precise management. The present and foreseeable economic scenario necessitates action now on cost cutting.

Start with an analysis of the present farm production system and financial returns. The e-Profit Monitor is the tool for this and is available to clients free on www.client.teagasc.ie. In addition to providing financial and technical advice, Teagasc advisors are now running short financial courses countrywide.

In the medium to long term there will be further challenges resulting from the mid-term review of CAP, enlargement of EU and WTO but there will also be opportunities. Technology will continue to improve efficiency and possibly provide us with alternative crops and alternative uses for our present crops.

Appendix 1

YEAR	Teagasc e-Profit Monitor : Tillage - All Crops / ha									20-Jan-03
2002										
Farmer				**Code**	**3800001**			Adviser	**Tom Adviser**	
FARM										
	Land Ha	109.4						Production Type	4. Cereals + Beet	
	Tillage Ha	109.4						Labour Units (Est.)	0.00	
Crop										
	Crop		**Total**	**Wint. Wheat**	**Sp.Wheat**	**Sp. Feed Barley**	**Sp. Malt. Barley**	**Wint. Oats**	**Beet**	**Set Aside**
	Owned Land		84.8	12.9	14.1	0.0	32.3	7.3	8.5	9.7
	Leased Land		24.7	0.0	0.0	17.4	0.0	4.9	0.0	2.4
	Total Tillage Adj. Ha		109.4	12.9	14.1	17.4	32.3	12.1	8.5	12.1
	Tonnes			118	116	147	182	106	380	0
	Tonnes / Ha			9.12	8.19	8.43	5.64	8.74	44.76	0.00
	Kg of N /Ha			0 /Ha	0 /Ha	0 /Ha	0 /Ha	0 /Ha	0 /Ha	0 /Ha
GROSS OUTPUT										
Sales	Crop		807	949	839	806	615	901	2,283	0
	Straw / Tops		33	16	0	43	59	66	0	0
	Bonus		7	0	0	0	0	0	90	0
Farm Output			**847**	**965**	**839**	**849**	**674**	**966**	**2,372**	**0**
	Premia & Direct Payments		352	383	383	383	379	382	0	383
	REPS		0	0	0	0	0	0	0	0
Gross Output			**1,199**	**1,348**	**1,222**	**1,232**	**1,053**	**1,348**	**2,372**	**383**
VARIABLE COSTS										
	Seed		61	54	73	61	59	57	146	0
	Fertiliser		137	150	143	145	137	131	294	0
	Lime		0	0	0	0	0	0	0	0
	Herbicide		48	49	37	26	26	38	279	0
	Fungicde		102	172	160	96	96	129	37	0
	Insecticide		0	0	0	0	0	0	0	0
	Growth Regs.		17	20	22	14	14	32	29	0
	Scutch Control		12	12	12	12	12	12	12	12
	Contractor	Plough /Till /Sowing	0	0	0	0	0	0	0	0
		Spraying	0	0	0	0	0	0	0	0
		Fert. Spreading	0	0	0	0	0	0	0	0
		Harvesting	0	0	0	0	0	0	0	0
		Other	22	3	3	2	2	2	259	0
	Levies and Transport		0	0	0	0	0	0	0	0
	Sundry Var. Costs		0	0	0	0	0	0	0	0
	Total Variable Costs		399	459	450	355	347	402	1,057	12
Gross Margin			**800**	**889**	**772**	**877**	**707**	**946**	**1,315**	**371**

contd……../

YEAR	Teagasc e-Profit Monitor : Tillage - All Crops / ha									20-Jan-03
2002										
Farmer				**Code**	**3800001**			Adviser	**Tom Adviser**	
FARM										
	Land Ha	109.4						Production Type	4. Cereals + Beet	
	Tillage Ha	109.4						Labour Units (Est.)	0.00	
Crop										
	Crop		**Total**	**Wint. Wheat**	**Sp.Wheat**	**Sp. Feed Barley**	**Sp. Malt. Barley**	**Wint. Oats**	**Beet**	**Set Aside**
	Owned Land		84.8	12.9	14.1	0.0	32.3	7.3	8.5	9.7
	Leased Land		24.7	0.0	0.0	17.4	0.0	4.9	0.0	2.4
	Total Tillage Adj. Ha		109.4	12.9	14.1	17.4	32.3	12.1	8.5	12.1
	Tonnes			118	116	147	182	106	380	0
	Tonnes / Ha			9.12	8.19	8.43	5.64	8.74	44.76	0.00
	Kg of N /Ha			0 /Ha	0 /Ha	0 /Ha	0 /Ha	0 /Ha	0 /Ha	0 /Ha
FIXED COSTS										
	Hired Labour		0	0	0	0	0	0	0	0
	Mach. Running		124	149	136	136	117	154	139	41
	Mach. Leases		0	0	0	0	0	0	0	0
	OD & Credit Int.		0	0	0	0	0	0	0	0
	Loan Interest		0	0	0	0	0	0	0	0
	Car (Farm)		48	54	49	49	42	54	94	15
	E.S.B. (Farm)		8	9	8	9	7	9	16	3
	Phone (Farm)		15	17	15	15	13	17	29	5
	Dep. Build.		0	0	0	0	0	0	0	0
	Dep. Machinery		114	139	126	127	107	139	129	38
	Repairs and Maint.		0	0	0	0	0	0	0	0
	Insurance		12	13	12	12	10	13	23	4
	Prof. Fees		12	14	12	13	11	14	24	4
	Sundry Fixed Costs		25	28	26	26	22	28	50	8
	Land Lease		76	0	0	362	0	115	0	50
	Total Fixed Costs		433	423	384	748	329	543	506	167
Net Profit			**367**	**466**	**388**	**128**	**378**	**403**	**810**	**204**
NOTES										
	Materials		377	456	447	354	345	399	798	12
	Contractor		22	3	3	2	2	2	259	0
	Machinery		238	288	262	263	224	293	268	79
Common Costs			756	882	834	742	676	830	1,563	129
Common Costs as % of Gross Output			**63%**	**65%**	**68%**	**60%**	**64%**	**62%**	**66%**	**34%**

Appendix 2

Profitability: FINPACK

		2002 Base Plan Base Year 2002	Alt 1 Contin02 Projected 2006	Alt 2 Rental Extra 40 ha	Alt 3 Labour – Contractor establish	Alt 4. Labour + eco till
Income Statement (typical year)						
Wheat cash winter	€92/tonne	11,512	12,461	12,461	33,327	33,327
Wheat, cash Spring	€97/tonne	11,215	12,036	12,036	12,036	12,036
Barley, cash Spring	€89/tonne	10,685	11,305	34,694	20,660	20,660
Barley, Malting	€108/t	24,070	25,116	25,116	25,116	25,116
Sugar Beets	€50/t	18,998	19,550	19,550	19,550	19,550
Oats Cash Winter	€89/t	9,469	9,6922	9,692	9,692	9,692
Misc Crop income		42,685	42,685	59,553	58,970	58,970
Wing-Beef	€117/100kg	31,188	31,188	31,188	31,188	31,188
Other Livestock income		15,200	15,200	15,200	15,200	15,200
Contract work income		3,976	4,452	2,240		3,360
(a) Gross Farm Income		**178,898**	**183,685**	**221,730**	**225,739**	**229,099**
Seed		6,744	7,527	9,975	9,802	9,802
Fertiliser		18,034	20,169	26,001	26,131	26,131
Herbicides		5,277	5,876	6,920	7,460	7,460
Other crop chemicals		13,019	14,547	18,975	20,963	20,963
Packaging and supplies		680	760	760	760	760
Livestock purch to feed		18,600	18,600	18,600	18,600	18,600
Purchased feed		2,400	2,400	2,400	2,400	2,400
Veterinary		600	600	600	600	600
Livestock supplies		200	200	200	200	200
Livestock mkting and tra		1,200	1,200	1,200	1,200	1,200
Interest		510	510	1,445	1,445	1,445
Fuel and oil		3,000	3,300	4,480	2,360	3,400
Machinery Repair		5,144	5,761	6,770	4,500	5,040
Other repair and Maint		1,796	2,011	2,464	2,011	2,240
Contractor costs		2,313	2,590	2,590	15,000	12,285
Hired Labour		21,426	23,997	23,997	4,000	2,000
Land lease and conacre		6,300	7.056	21,900	21,900	21,900
Farm Ins		2,359	2,642	2,800	2,800	2,240
Car, ESB and phone		7,747	8,676	8.736	8,736	8,736
Dues and Prof Fees		1,337	1,497	1,497	1,497	1,497
Misc		1,607	1,799	1,904	1,904	1,904
(b) Total Cash Farm expense		**120,293**	**131,719**	**164,215**	**154,269**	**150,803**
(c) Net Cash Farm Income		58,605	51,966	57,515	71,470	78,296
Depreciation		15,189	15,189	15,189	11,000	12,000
(d) Net Farm Income		**43,416**	**36,777**	**42,326**	**60,470**	**66,296**

Appendix 3

Variable inputs costs for conventional and reduced input system (1996-2001)

	Input costs (€/ha)*	
Crop	Conventional	Reduced
Winter Wheat	549	386
Winter Barley	456	311
Winter Oats	427	290
Spring Barley	288	205

* Cost of seeds, fertiliser and pesticides (including interest)

Appendix 4

Effect of conventional (high) and reduced input systems on the grain yield of cereals grown in different rotations (1996-2002)

		Grain yield (t/ha at 15% DM)	
Crop	**Treatments (Rotations)**	**Conventional**	**Reduced**
Winter Wheat	Break-up	11.28	10.72
	Rotation	11.65	10.96
	Continuous	10.81	10.04
	Mean	11.25	10.57
Winter Barley	Break Crop	9.58	8.63
	Rotation	9.37	8.09
	Continuous	9.42	8.06
	Mean	9.46	8.26
Winter Oats	Rotation	9.20	8.27
Spring Barley	Break Crop	7.44	6.31

Maximising Returns From Fungicide Use in Cereals

B. Dunne
Teagasc
Crops Research Centre, Oak Park

SUMMARY

The 2002 cropping season was characterised by high disease pressure in winter and spring barley and winter wheat. Significant yield responses to fungicide application were obtained in all three crops. In winter wheat, where *Septoria tritici* was severe, results indicated that the key timings for fungicide application were growth stages (GS) 32 and 39. Inclusion of the curative activity of epoxiconazole in the GS 32 spray, either alone or in mixture with a strobilurin fungicide, gave good disease control and yield responses. The GS 39 spray should consist of a strobilurin product with a robust rate of a triazole product added where disease levels in the crop are high. In the absence of significant ear fusarium levels, applying a third spray at GS 59 gave a relatively small yield response in 2002.

In spring barley yield responses s of 1.0-1.5 t/ha were obtained. Despite these yield responses the economic returns from fungicide application were generally modest emphasising the need for careful control of fungicide spend. *Ramularia collo-cygnii* was prevalent in spring barley trials in 2002 and where it was severe yield responses to fungicide application of 1.0 t/ha were achieved. Results indicate that epoxiconazole and chlorothalonil are the two most effective active ingredients for its control. It is concluded that inclusion of epoxiconazole with a strobilurin fungicide in the flag leaf spray on spring barley will give control of traditional disease as well as Ramularia. Chlorothalonil could be substituted for the triazole where traditional disease levels are low at the time of flag leaf application.

INTRODUCTION

The 2002 season was a difficult year for cereal growers. A wetter than normal summer resulted in a major epidemic of *Septoria tritici* in winter wheat while Ramularia on barley affected yields in this crop. Despite the wet weather ear Fusarium, surprisingly, remained at very low levels. The lower than normal levels of sunshine undoubtedly reduced yield potential in many crops.

Disease control in winter wheat requires a three-spray programme at GS timings of 31/32 (T1), 39 (T2) and 59/65 (T3). In 2002, as there were high levels of Septoria in crops by early spring, some growers applied a pre-T1 or T0 spray. The timing for this spray was between GS 25 and GS 30. While the fungicide costs for this spray are low, as either chlorothalonil or reduced rates of triazoles are used, the application cost has to be considered unless it coincides with a herbicide application.

Disease control in winter barley is normally achieved with a two-spray programme. Rhynchosporium and net blotch are the two main target diseases but in 2002 there was a response to Ramularia control.

Spring barley also requires a two-spray programme to achieve season long disease control. Spring barley yields were disappointing in 2002. Disease was a factor in reducing yields but climatic conditions also played a role.

WINTER WHEAT FUNGICIDES

In 2002, winter wheat fungicide trials were carried out in Oak Park, Co. Carlow, Kildalton, Co. Kilkenny and at Lismore, Co. Waterford. These trials examined the yield and disease responses to fungicide timings and fungicide programmes.

Effect of Spray Timing

Opera, at a rate of 1.0 l/ha, was applied at each of the recommended growth stages for spraying i.e. GS 31/32, 39 and 59/65. The fungicide was also applied as two- and three-spray programmes at various combinations of the same growth stages. The results for these trials are shown in Table 1.

Table 1 shows the very low unsprayed yields reflecting the high disease pressure in this season. It also shows that septoria levels were much higher at the Lismore site than at Oak Park. The variety at Lismore was Savannah while that at Oak Park was Madrigal.

There was a significant yield response to single fungicide applications at both sites. A single spray applied at GS 32 gave a yield increase over the untreated of 45% and a single spray at GS 39 gave a corresponding increase of 56%. A two-spray programme with fungicide applied at GS 32 and 59 (omitting the GS 39 spray) returned a yield increase of 58%. In a three-spray programme where the GS 39 spray was included, a 97% yield increase over the untreated was obtained. This emphasises and reiterates the importance of the contribution of the GS 39 application in controlling foliar diseases and increasing yield. The relatively small yield increase obtained when the two-spray programme (GS 32 and 39) is compared with the three-spray programme (where a GS 59 fungicide was applied) indicates the relatively small contribution of the GS 59 spray when adequate GS 32 and 39 sprays were applied.

Table 1: Effect of spray timing on disease control and grain yield

Timing	Treatment	Rate (l/ha)	% Septoria 2nd leaf **Lismore**	% Septoria 2nd leaf **Oak Park**	Yield (t/ha, 15% m.c) **Lismore**	Yield (t/ha, 15% m.c.) **Oak Park**	Average % yield increase (Two sites)
GS31/32 GS39 GS59	Opera	1.0	100	76	6.26	8.06	45
GS31/32 GS39 GS59	 Opera	 1.0	76	51	6.50	8.86	56
GS31/32 GS39 GS59	Opera Opera	1.0 1.0	77	11	8.23	10.26	89
GS31/32 GS39 GS59	Opera Opera	1.0 1.0	95	87	6.69	8.92	58
GS31/32 GS39 GS59	Opera Opera Opera	1.0 1.0 1.0	82	4	8.38	11.05	97
	Unsprayed		100	98	4.32	5.54	
	L.S.D.		20	14	0.64	0.8	

Growth Stage 32 (T1) Fungicides

A second trial at Lismore examined the effect of thirteen different fungicide treatments applied at GS 32. All treatments received a common GS 39 spray (Opera 1 l/ha and a common GS 59 spray (Amistar at 0.5 l/ha). The rate of products used at this spray timing was determined such that each T1 treatment would cost approximately €50 per hectare (€20 per acre). The results from this trial are shown in Table 2.

All fungicide treatments significantly out-yielded the untreated. There were also significant differences between treatments for both percentage disease and yield. As Septoria was very severe at this site it is to be expected that the amount of epoxiconazole applied would have a corresponding effect on yield. Generally, Septoria levels on the second leaf reflect the level of Opus used at the T1 spray timing. The highest yielding treatments reflected the amount of epoxiconazole applied, with the highest yield being obtained where full-rate epoxiconazole was used.

Table 2. Effect on yield and disease of various fungicides applied at GS 32 (Lismore, Co Waterford)

Fungicide Applied at T1 (T2 and T3 common)	Rate (l/ha)	Epoxiconazole a.i. (g/ha)	% Septoria Flag leaf	% Septoria 2nd leaf	Yield (t/ha, 15% m.c.)
Opera	1.0	50	12	75	8.02
Opus + Unix	0.5 + 0.5	62.5	12	82	8.62
Acanto + Unix	0.5 + 0.5	-	31	97	7.56
Allegro	0.8	100	8	86	7.86
Allegro + Unix	0.5 + 0.5	62.5	10	85	8.27
Opera + Unix	0.5 + 0.5	25	15	88	7.60
Opus	1.0	125	11	73	8.81
Flamenco Plus	2.3	-	7	81	7.95
Sphere + Unix	0.6 + 0.3	-	11	92	7.85
Allegro	0.4	50	13	88	8.08
Allegro + Unix	0.3 + 0.3	37.5	14	91	7.61
Sportak	0.9	-	11	97	8.01
Opera	0.75	37.5	17	81	8.29
Unsprayed			33	97	4.50
L.S.D.			14	13	0.65

The treatments of Opus + Unix (0.5 l/ha + 0.5 kg/ha) and Allegro + Unix (0.5 l/ha + 0.5 kg/ha), which have performed well in previous years, were among the higher yielding treatments. When the rates of the Allegro + Unix mixture were reduced to 0.3 l/ha + 0.3 kg/ha however there was a significant yield reduction indicating that when disease pressures are high, reduced fungicide rates can under-perform. In less disease prone seasons, however, this lower rate has given satisfactory performance.

Effect of Strobilurins and Non-Strobilurins

Strobilurin containing fungicides were compared with non-strobilurin containing fungicides at each spray timing. The results from these treatments are shown in Table 3.

A three-spray strobilurin programme was significantly higher yielding than a three-spray non-strobilurin programme at both sites. There was no significant yield difference at either site between a strobilurin (Opera) and a non-strobilurin (Unix + Opus) when used at the T1 spray timing at either site. The latter was higher yielding at Lismore and the former was higher yielding at Oak Park.

At the T2 spray timing, where the T2 and T3 sprays were common, there was a yield difference in favour of the non-strobilurin (Opus) over the strobilurin (Opera) at Lismore with a consequent reduction in disease levels on the second leaf. At Oak Park there was no difference. The explanation for this variation lies in the fact that there was higher disease pressure at Lismore. The Opus treatment supplied 125 g/ha epoxiconazole compared with 50 g/ha epoxiconazole in the Opera treatment, which resulted in greater control of Septoria, preserving more green leaf area.

The use of strobilurins at T2 has been proven to have yield benefits. However, it is necessary in high disease pressure situations to ensure that a robust rate of a triazole is used as a partner in the fungicide mixture applied.

Table 3: Effect of strobilurins and non-strobilurins at various spray timings

Timing	Treatment	Rate (l/ha)	% Septoria 2^{nd} Leaf **Lismore**	% Septoria 2^{nd} Leaf **Oak Park**	Yield (t/ha,15% m.c.) **Lismore**	Yield (t/ha,15% m.c.) **Oak Park**	Average % yield increase (Two sites)
GS31/32	Opus+Unix	0.5+0.5	90	33	8.00	9.59	80
GS39	Opus	1.0					
GS59	Opus	1.0					
GS31/32	Opera	1.0	82	4	8.38	11.05	97
GS39	Opera	1.0					
GS59	Opera	1.0					
GS31/32	Opus+Unix	0.5+0.5	84	18	8.82	10.42	97
GS39	Opera	1.0					
GS59	Opera	1.0					
GS31/32	Opera	1.0	66	12	8.99	10.95	104
GS39	Opus	1.0					
GS59	Opera	1.0					
GS31/32	Opus+Unix	0.5+0.5	89	13	8.68	10.33	94
GS39	Opera	1.0					
GS59	Opus	1.0					
	Unsprayed		100	98	4.32	5.54	
	L.S.D.		20	14	0.64	0.8	

SPRING BARLEY FUNGICIDES

Fungicide trials were carried out at Oak Park, Co. Carlow and at Midleton, Co. Cork. Optic was the variety grown at each site.

The objective of the trials at Oak Park and Midleton was to investigate the disease control, yield and economic response from a number of fungicide programmes, either one- or two-spray, costing approximately either €50 per hectare (€20 per acre) or €80 per hectare (€33 per acre). Results are shown in Table 4.

In general, yield and economic responses to fungicide application were low to moderate at both sites.

At the Oak Park site all treatments were significantly higher yielding than the unsprayed. The average yield of the €20/acre programmes was 5.95 t/ha (0.75 t/ha over the unsprayed) and the average yield of the €33/acre programmes was 6.27 t/ha (an average of 1.1 t/ha over the unsprayed). Assuming a grain price of €100/tonne @ 15% moisture this gives a margin over fungicide costs (MOFC) of €10.4 per acre for the €20 programmes and €11.3 per acre for the €33 programmes.

While this return is low there were individual treatments which gave a much higher return than the average MOFC. For example, the two-spray programme using Allegro gave a MOFC of €24.3 per acre and the single spray at T2 of Acanto + Opus (0.5 + 0.5) gave a MOFC of €21.3 per acre.

Diseases present in these crops were Rhynchosporium and later Ramularia. Many of the higher yielding treatments included Opus at T2. These treatments also had the highest percentage green leaf area. This is a reflection of the effectiveness of Opus against Ramularia and other foliar diseases.

At the Midleton site, where Rhynchosporium and Ramularia were present, all treatments were also significantly higher yielding than the unsprayed. However, there were smaller yield differences between individual treatments than at Oak Park. The MOFC at Midleton for the €20 per acre programmes was €10.8 while that for the €33 per acre programmes was €6.80.

Table 4: Effect of fungicide programmes on spring barley (cv. Optic) on yield and MOFC at Oak Park and Midleton 2002

Treatment	Rate (l/ha)	Cost (€/acre)	Oak Park		Midleton	
			Yield (t/ha, 15% m.c.)	MOFC (€/ac)	Yield (t/ha, 15% m.c.)	MOFC (€/ac)
Punch C	0.5	14.00	5.68	5.4	5.06	5.8
- Opus + Corbel	 0.7 + 0.3	16.90	6.12	20.2	5.28	11.7
Stereo Acanto	0.75 0.5	19.05	5.71	1.6	5.26	8.9
Corbel Acanto	0.5 0.5	19.20	5.72	2.1	5.39	14.2
Allegro Allegro	0.3 0.4	19.25	6.27	24.3	5.50	18.7
- Twist + Opus	 0.75 + 0.5	19.50	5.93	9.6	5.13	2.7
- Acanto + Opus	 0.5 + 0.5	20.75	6.22	21.3	5.48	15.8
Stereo Twist	0.75 1.0	21.3	5.79		5.40	12.6
Tilt Acanto	0.5 0.66	21.5	5.94	9.0	5.16	1.9
- Opera	 1.0	21.60	5.96	8.8	5.18	2.7
Stereo Punch C	0.75 0.625	21.6	6.04	13.0	5.49	15.2
 Allegro + Corbel	 0.7 + 0.3	23.70	5.89	3.9	5.36	8.0
- Acanto + Opus	 0.8 + 0.8	33.19	6.16	5.9	5.30	0
Acanto Acanto + Opus	0.5 0.5 + 0.5	32.5	6.20	8.5	5.62	9.5
Stereo Twist + Opus	1.0 1.0 + 1.0	33.0	6.56	22.1	5.62	9.5
Acanto + Opus -	0.8 + 0.8	33.19	6.21	7.9	5.46	3.0
Sanction + Corbel Acanto + Opus	0.2 + 0.5 0.5 + 0.5	34.0	6.25	8.5	5.72	12.6
Stereo Covershield	1.0 1.0	34.0	6.45	16.6	5.58	6.9
Stereo Charisma	1.25 1.5	34.22	6.02	0	5.43	0.8
Unsprayed			5.20		4.57	
L.S.D.			0.3		0.29	

Ramularia

Ramularia collo-cygnii was prevalent on many spring barley crops at significant levels in 2002. The control of this disease with fungicides was investigated at Oak Park. A trial was carried out in which a number of products were applied, at the full recommended rate, at GS 69 (28 June 2002). At the time of fungicide application most of the leaves in the crop were abundantly infected with Rhynchosporium indicating that any yield response to fungicide was not solely attributable to control of leaf disease. Therefore any yield response were due to protection of the stem, ears and awns of the crop. High levels of Ramularia appeared in the crop subsequent to spraying. The results of this trial are shown in Table 5.

Table 5: Yield response to GS 69 fungicides on spring barley variety Optic - Oak Park

Fungicide	Rate (l/ha)	Yield (t/ha, 15% m.c.)	% yield increase
Bravo	2.0	6.81	21
Opus	1.0	6.66	18
Allegro	1.0	6.43	14
Folicur	1.0	6.22	10
Amistar	1.0	6.12	8
Modem	1.0	6.05	7
Caramba	1.5	5.97	6
Unix	0.75	5.97	6
Sanction	0.5	5.96	5
Untreated		5.65	0
L.S.D.		0.4	

Bravo, Opus and Allegro treatments were significantly higher yielding than the untreated, but were not significantly different in yield response from each other, but they were significantly higher than all treatments except Folicur. Both chlorothalonil and epoxiconazole are effective against Ramularia so it is not surprising that these products gave a significant response. The strobilurins and other triazoles have limited effect against Ramularia although Amistar and Modem were significantly higher yielding than the untreated while Caramba, Sanction and Unix were not.

An important observation was that while chlorothalonil gave a visually stricking effect compared to other treatments, it did not give a significant yield increase over epoxiconazole. It is unlikely that chlorothalonil would be used on its own at the T2 timing in barley as it gives insufficient control of diseases such as Rhynchosporium and net blotch. If a robust rate of Opus is included at T2 the financial return from adding chlorothalonil is likely to be minimal.

Winter Barley Fungicides

A trial was carried out on winter barley variety Regina at Oak Park. All treatments were applied as two-spray programmes. Disease levels were low during the growing season but Ramularia became evident after the crop had headed. Fungicide treatments were applied to this crop at GS 32 and 59. The results for this trial are shown in Table 6.

Table 6: Two-spray programme trial on Regina winter barley - Oak Park 2002

Fungicide	Rate (l/ha)	% Necrosis Flag leaf	% Necrosis 2nd leaf	% Screenings 2.0 mm	Kg/hl	Yield (t/ha, 15% m.c.)
Opera Opera	1.5 1.5	7	29	2.6	57.9	9.06
Opera + Corbel Opera	1.2 + 0.3 1.5	7	32	2.5	57.0	9.03
Covershield Covershield	1.5 1.5	7	21	1.9	57.7	9.07
Allegro + Corbel Opera	0.8 + 0.3 1.5	6	27	2.3	57.2	9.06
Punch C + Allegro Punch C + Twist	0.8 + 0.4 0.6 + 1.2	17	60	2.6	56.6	8.72
Sphere + Unix Twist + Opus	0.8 + 0.4 1.2 + 0.5	12	45	3.0	55.2	8.62
Punch C + Modem Charisma + Acanto	0.6 + 0.5 1.0 + 0.8	25	62	3.1	55.8	8.51
Stereo + Acanto Stereo + Acanto	1.2 + 0.8 1.8 + 0.8	18	43	2.8	55.3	8.50
Punch C + Acanto Punch C + Amistar	0.6 + 0.5 0.6 +1.0	24	61	2.7	55.8	8.41
Punch C + Twist Punch C + Acanto	0.8 + 1.2 0.6 + 0.8	23	59	2.6	55.4	8.38
Untreated		46	81	3.5	55.5	7.85
L.S.D.		9	12.4	0.7	1.2	0.27

There was trace amounts of Rhynchosporium in this crop. The main disease contributing to leaf necrosis on the flag and second leaves was Ramularia. All treatments were significantly higher yielding than the unsprayed. Four of the treatments were significantly higher yielding and also gave significantly lower levels of leaf necrosis than all the other treatments. These four treatments all contained epoxiconazole as a component of the fungicide products applied indicating the effectiveness of this fungicide against Ramularia.

CONCLUSIONS

1n 2002 T1 and T2 fungicide applications on winter wheat gave similar yield increases.

The effect of the T1 treatment lasted through the season. The T1 timing can be either GS 31 or GS 32. However, in 2002, the T1 spray was applied at GS 32 and performed well. At GS 32, the third leaf is emerging and applying a fungicide at this timing gives maximum protection. It is also a good time for controlling eyespot. Spraying at GS 31 also gives good control of eyespot but will reduce the protection of the third leaf and will lengthen the time interval between T1 and T2, a scenario that occurred in 2002. Best results were obtained when the T2 was applied at GS 39 (i.e. when the flag leaf is fully expanded).

The GS 59/65 (T3) spray timing gives a small yield response if strong T1 and T2 sprays have been applied at the correct time. This spray reinforces the effect of the earlier sprays and controls ear fusarium.

There was a large variation in the financial returns from various fungicide programmes in spring barley. As the yield responses from disease control are usually moderate (1 t/ha – 1.5 t/ha) the fungicide products used and their costs have to be critically chosen. The primary consideration has to be the disease situation and disease risk in the crop at the time of spraying. The product chosen and the dose rate will be determined by these factors. Spring barley disease control costs need not be excessive.

Energy Crops – Have They a Future?

B. Rice
Teagasc
Crops Research Centre, Oak Park

SUMMARY

Energy production from biomass can reduce greenhouse gas emissions, provide a secure native fuel source and provide some diversification out of traditional farm enterprises. Most EU countries have launched programmes to promote biofuel production, but to date there has been little progress in Ireland.

Pressures to reduce greenhouse gas production must be expected as the effort to achieve Kyoto targets intensifies. Some abatement of ammonia emissions is also required to comply with international commitments. To achieve these targets without reducing output, digestion and low-emission spreading of animal slurry to minimise methane and ammonia emissions are the most promising options.

If liquid biofuel crops (for vegetable oil or ethanol) were grown on the existing set-aside area, they could supply about 10% of the agricultural fuel demand. To meet the full agricultural fuel demand, an area of about 0.3 Mha (6% of the farmed area) would be needed.

Where the whole of an energy crop is utilised in a heating or CHP plant, about 0.5Mha would be required to meet 10% of the total national energy demand. At the extreme, the total farmed area could produce an amount of energy roughly equivalent to our national demand.

By-product materials such as wood residues, straw, tallow and recovered vegetable oil are reasonably priced feedstocks that could help get biofuel industries started. Conversion technologies are now well established and in practical use in other EU countries. Such incentives as have been available in Ireland to date to stimulate renewable energy production have not been sufficient to bring about the establishment of viable projects. To allow a beginning to be made, two changes are needed immediately: a reduction or remission of road excise on biofuels and an increased price for electricity from biomass. Since the size of the biomass resource is limited and no exchequer costs are incurred until the renewable energy is produced, these measures could be introduced at very little cost or risk to the economy.

INTRODUCTION

The concept of using farm crops or by-products as fuels has received much attention after each oil crisis of the past thirty years. It also came to the forefront when set-aside land was introduced in the early nineties. However, while much technical progress has been achieved, possibilities for commercial development have always waned as soon as plentiful supplies of cheap fossil fuel were restored.

Yet there are some indications that we are about to see a more sustained interest in the development of biofuel industries:

- The need to control the rise in greenhouse gas (GHG) and ammonia emissions is getting more urgent. This in turn will create problems and opportunities – problems with the high level of emissions from our current farm enterprises, but also opportunities to produce energy from crops and wastes.
- The days of abundant supplies of fossil fuel, in particular oil, are coming to an end. All sources of alternative energy, especially renewable sources, will need to be developed rapidly to take up the slack.
- Falling margins and market difficulties with conventional farm enterprises are increasing the need to diversify into alternative markets.

In other EU countries, considerable progress has been made with the establishment of biofuel industries. The use of wood for heat and electricity in Austria and the Scandinavian countries, vegetable oil as a fuel for diesel engines in France and Germany, and biogas production from animal manure in Denmark and Germany, are now substantial established industries. Ethanol production has grown to a major industry in the USA and Brazil. These developments have been achieved by a combination of taxes on fossil fuels and incentives for renewables, at a level sufficient to allow the establishment of viable biofuel industries.

To date there has been no significant development of biofuel use in Ireland. Wood as fuel amounts to less than 1% of our total energy requirement. The only other biomass use of any significance is beef tallow, some of which is now being used as boiler fuel for process heat by the rendering industry. This lack of progress has not been due to lack of interest by potential investors. The big problem has been the continued low price of mineral fuels, and the low level of state financial support that has been available for renewable energies. Prices for electricity from biomass in earlier rounds of the national Alternative Energy Requirement programme have not been sufficient to attract investors, and excise rates on liquid biofuels has been maintained at the same level as those on fossil equivalents.

GREENHOUSE GAS AND AMMONIA EMISSIONS

Agriculture accounts for about one-third of GHG emissions, so efforts to reduce them will inevitably focus on the farming sector.

Of the approximately 24 Mt of CO_2-equivalent emissions attributed to agriculture, the major sources are methane from ruminant animals and slurry handling, nitrous oxide from soils and CO_2 from fuel use.

The National Climate Change Strategy, the Government's initial response to the task of meeting Kyoto targets, aims to balance the need to reduce emissions with the maintenance of farm incomes and employment (Department of Environment & Local Government, 2000). It sets out a target to reduce emissions from agriculture by 10% or 2.4 Mt, by the following means:

1. Reduce methane emissions from the national herd by 10% below "business as usual" 2010 levels; this to be achieved by a combination of reduced stock numbers and changes in herd management practices.
2. Increase afforestation.
3. Develop short-rotation biomass and anaerobic digestion of animal wastes.
4. Reduce N fertiliser use by 10%.
5. Promote best practice guidelines.

The mention in Item 3 of biomass and digestion is a recognition of the roles they could play in emission reduction, though the singling out of short-rotation crops is difficult to understand. Biogas production from 75% of the pig industry and 10% of the dairy industry would reduce emissions by about 80 kt, or 3% of the reduction target for farming. The use as fuels of other by-product materials such as wood wastes, tallow, some straw and recycled vegetable oil could reduce emissions by over 0.5 Mt CO_2, or up to a quarter of the target. The GHG reduction from growing biomass crops would range between 3 and 15 t/ha of CO_2, depending on the crop grown and the fuel produced. So if the entire reduction target had to be met in this way, a crop area between 160,000 and 800,000 ha would have to be grown.

In parallel with the Kyoto agreement on GHG emissions, the Gothenburg Protocol binds Ireland to reductions in acid-precursor emissions over the same 1990-2010 period (United Nations, 1999). From the viewpoint of agriculture, ammonia is the main concern, since 90% of ammonia emissions come from agriculture.

Ireland is committed to a 9% reduction of national ammonia emissions. Of the total of about 120 kt of ammonia emitted from farms, the main target for reduction should be that from the spreading of animal manure, which accounts for about 28% of the total. If 50% of slurry were band-spread, the reduction target should be comfortably achieved.

POTENTIAL FOR ENERGY PRODUCTION FROM BIOMASS

The total potential for energy production from farm produce can be estimated by adding the potential from energy crops to that from by-products of existing enterprises.

From crops whose total production is converted by some form of combustion to heat, an energy yield from 100 to 200 GJ/ha might be achieved, depending on the crop selection, land quality etc. Assuming that an average energy yield of 125 GJ/ha could be achieved, an area of over 0.5 Mha would be required to produce 10% of national primary energy requirement, i.e. more than the current arable area (Fig. 1). At the extreme, the total Irish land resource could just about produce the national primary energy requirement.

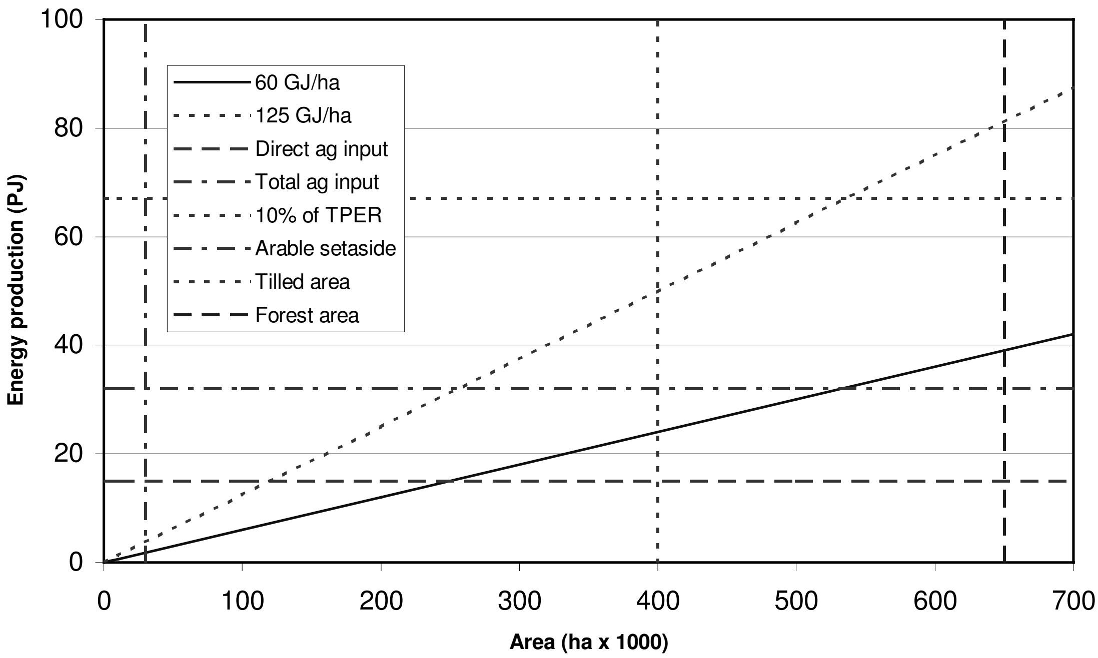

Fig. 1: Potential for energy production from crops grown for direct combustion (forestry, coppice, hemp, miscanthus, whole-crop cereals etc.) and for liquid biofuel production (rape-seed, cereals, sugar-beet etc.)

Crops grown solely for liquid biofuel production (e.g. rape-seed for biodiesel, cereals or beet for ethanol) would produce a lower amount of energy, probably about 60 GJ/ha. Crops for these purposes are more likely to be annual arable crops. If the full arable set-aside area were devoted to them, about 15% of the agricultural fuel requirement could be produced. To supply the full agricultural fuel oil need would require an area comparable to the current arable area to be devoted to it.

It is clear from these figures that biomass crops have the potential to become substantial suppliers of energy to the Irish market, but that large areas of land would have to be diverted from the traditional enterprises to achieve this. The big question is to what extent it is to our advantage to make this substitution. The environmental advantages are clear, the fuel market is enormous and the strategic value of a secure fuel supply is almost certain to appreciate. On the debit side, current fossil fuel prices are variable but still low, and substantial support would be required to make biofuels competitive with their fossil counterparts at present fuel prices.

The main by-product materials that could make a contribution are as in Table 1. Some of these materials (e.g. straw) have existing markets which underpin their price; others have more limited outlets. Also materials such as slurry from small dry-stock units could hardly be utilised economically, and forest residues would be better left in situ on many sites. A rough estimate of the volumes that might be available at a reasonable price and the amount of energy they might produce is given in Table 1. This amount of energy is equivalent to the production of about 80,000 ha of energy crops. It is a substantial resource of relatively low-cost raw material, which could provide a starting-point for a number of biofuel industries.

Of the many possibilities for producing biofuels from farm produce, four of the more likely possibilities for Ireland are considered here:

- Biogas from animal manure
- Heating or diesel engine fuel from vegetable oils or animal fats
- Ethanol from sugar beet, cereals or cellulosic materials
- Electricity and/or heat production from biomass crops and residues

Table 1: Potential for energy production from residue materials

Material	Potential resource (kt)	Calorific value (MJ/kg)	Energy form	Total energy production (PJ)
Forest residues	200	13	Heat	2.6
Cereal straw	70	13	Heat	0.9
Manures	30000	0.07	Methane	2.1
Oils/fats	50	35	Liquid biofuel	1.8
Total				7.4

BIOGAS FROM ANIMAL MANURE

Biogas is produced when organic materials such as animal manures are allowed to break down under airtight conditions. It consists of about two-thirds methane, much of which would have been released to the atmosphere during conventional storage, mixing and spreading. Adoption by 75% of the pig sector and 10% of the dairy sector would allow about 10 MW of electricity to be produced. A difficulty would arise in the utilisation of small amounts of a bulky gas at dispersed locations.

The main possibility to reduce ammonia emissions is to use a low-emission slurry spreading system. One limitation to the adoption of low-emission spreading is the problem of blockages in the small-bore distribution lines. Digestion would greatly reduce this problem; after digestion the slurry would be much more easily handled.

In summary, a combination of low-emission slurry spreading systems and slurry digestion could achieve a combination of useful objectives:

- Digestion would ease the blockage problems that are limiting the uptake of low-emission spreading.
- Both would contribute to a reduction of slurry smells during spreading.
- The required 9% reduction in ammonia emissions would be achieved.
- Methane emissions from animal wastes would be reduced by the equivalent of about 80 kt of CO_2.
- Crop utilisation of slurry N would be quicker and more predictable, so the opportunity to substitute slurry N for mineral N would be increased.
- About 1 PJ of energy could be produced. This would be roughly equivalent to the output of continuously running a 10 MWe generator.

However, the saving in fertiliser and return from energy production would not on its own justify the investment in digesters and low-emission spreaders. Some form of incentive will be required if any significant development is to take place.

OILS AND FATS AS HEATING OR DIESEL ENGINE FUELS

Vegetable oils and animal fats can provide a source of renewable fuel, either for diesel engines or heating systems. Some of these uses are already well developed, others are still under development (Fig. 2).

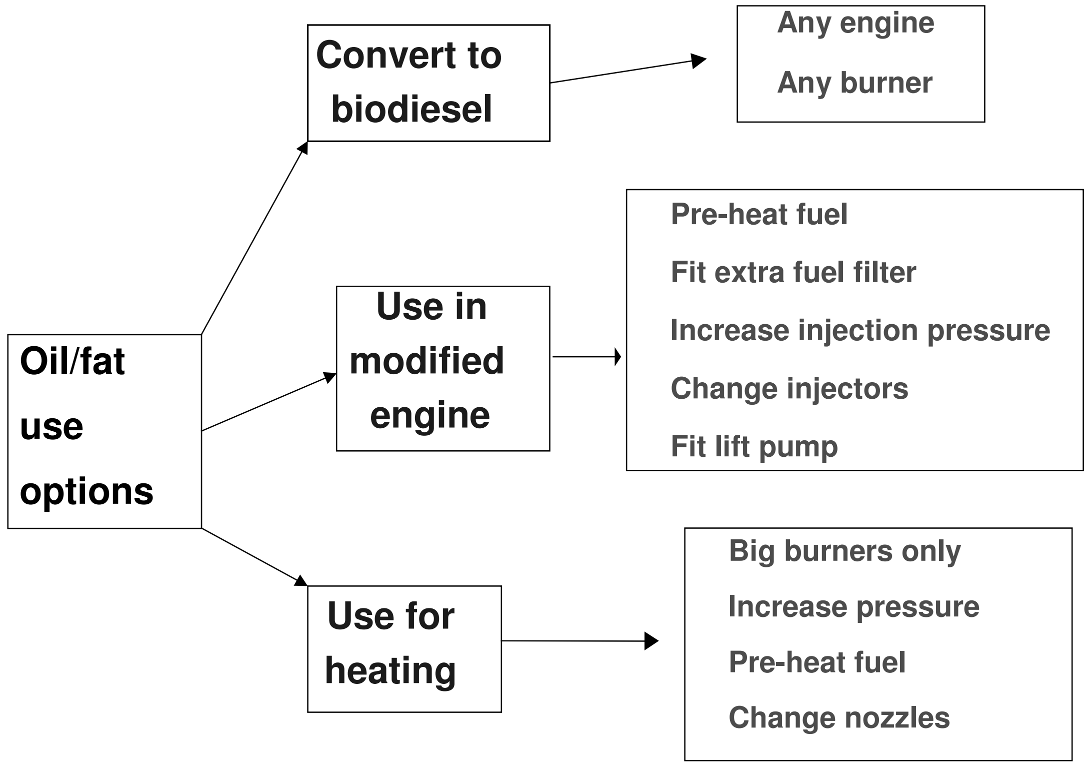

Fig. 2: Options for the use of oils and fats as fuels

Oils and fats can be used as engine fuels in two ways:

1. ***In unprocessed form with modifications to the engine:*** This use is relatively new but developing rapidly in Germany; thousands of engine conversion kits have been installed and are working well. The conversion consists of some combination of fuel pre-heating, extra filtration, increased injection pressure and replacement injectors. Fuel processing cost and industry start-up costs are kept to a minimum. This approach would have particular relevance in Ireland at present; it needs a low capital investment, the by-product cake can be used locally, and it is possible to start small and expand later. A number of small projects are already under way or being planned in Ireland at present.

2. ***Converted into biodiesel, no engine modification:*** This use is widely accepted and supported by the vehicle industry. An EU Standard (EN 14214) for biodiesel has been recently ratified. Numerous trials have demonstrated its environmental advantages as a fuel. About 1 Mt/yr is produced and used in the EU. It requires substantial plant investment, and processing adds about 5-10 cents/litre to the final cost of the fuel. Many attempts have been made to launch biodiesel projects in Ireland. To date they have been

unsuccessful, and it must be expected that this will remain the case until a long-term commitment to some reduction of liquid biofuel excise is forthcoming.

The use of these fuels for heating in large-scale burners is technically feasible, but economic viability depends on a very low raw material price, competitive with heavy-grade mineral oil. For domestic-scale heating units, the availability of suitable burners at a reasonable price remains a problem.

Currently, the main fuel use of oils/fats in the EU is biodiesel produced from rape-seed crops grown on set-aside land. The current CAP review is considering a change to the Area Aid rules that would no longer allow biofuel production on set-aside. The proposed alternative, a 45 €/ha payment on a maximum of 1.5 Mha is unlikely to make any impact. At the same time the EU Transport Directorate has been trying to oblige member states to meet mandatory liquid biofuel production targets. Communication between Directorates would appear to have temporarily broken down. When a final agreement is reached, it is hard to envisage an outcome that would seriously damage the viability of the fledgling biodiesel industry.

A cheaper raw material is recycled vegetable oil (RVO) from caterers. The use of this material in animal feeds has been disrupted since the 1999 Belgian dioxin-in-chickens incident, which was traced to RVO. It is now banned from animal feed throughout the EU, though Ireland and UK have a derogation until 2004. If no alternative use is found in this country, two possibilities arise:

- Collection will shrink, and more will be dumped into sewers and landfills.
- It will be exported for biodiesel production to Northern Ireland, which will benefit from the introduction of a 20p/litre excise remission in their 2002 budget.

Up to 10 kt/yr RVO could be collected. Oak Park research, together with research and practical experience in Austria, is showing that it can be used to make good quality biodiesel. Use as heating fuel is also feasible, and is likely to be tried out in practice in Ireland in the near future. Direct use in converted vehicle engines is a possibility that is being tried out by a Cork-based company at present. It is likely that some more research will be required before it can be fully endorsed.

Beef tallow, whose market as an animal feed has been disrupted by BSE, is another potential biofuel. Total tallow production is about 60 kt, two-thirds of which goes to animal feed. The disposal of tallow from the rendering of BSE-risk offal (ca. 3-5 kt) has been resolved by its use in boilers in rendering plants. The long-term future of tallow as animal feed is in some doubt, and alternative outlets are very desirable. Three possibilities arise: heating, combined heat and power (CHP) or biodiesel feedstock. All are technically feasible; profitability will decide which comes into practice. At present, tallow is being used as a heating fuel by some Irish rendering plants. A proposal to run a CHP plant on tallow is being examined, but may require a more favourable electricity price than is currently available to make it viable.

While the price difference between these fuels and fossil diesel has narrowed significantly in recent years, they still need some pump-priming support in the early stages of competition with fossil fuels. Present production costs vary from about 30 cents/litre for clean RVO used unprocessed to over 50 cents/litre for biodiesel from fresh rape-seed oil. This compares with about 30-35 cents/litre for mineral diesel before excise, VAT and distribution costs.

Some EU member states (e.g. France, Germany and Italy) promote vehicle biofuel production by reducing or abolishing road excise. In the UK, a remission of 20p/litre on biodiesel was introduced in 2002. At this stage, virtually all of Europe except Ireland has some form of support for vehicle biofuels. The UK measure is likely to stimulate considerable biodiesel production, and in the absence of similar action here, a cross-border traffic in feedstocks may well develop.

The EU has been considering proposals from the Transport Directorate to oblige member states to achieve target substitution rates of mineral fuels by their equivalent biofuels. The targets proposed begin with 2% by December 2005, extending to 5.75% by 2010. The proposal has now been watered down to remove any obligation, but an increase in EU liquid biofuel use remains a Transport Directorate priority. To meet the 2% target on the diesel side, Ireland would need to use 40 kt of oils/fats as vehicle fuel. A possible combination of feedstocks would be as follows:

20 kt	rapeseed oil from 20,000 ha
15 kt	tallow
5 kt	RVO

At a similar level of support to the UK excise remission, the maximum cost to the exchequer of this scale of production would be 10 M€/yr. Unlike the UK action (which is restricted to biodiesel), the support should be provided for any use of oils or fats as vehicle fuels. The market could then dictate which technologies are most appropriate in Ireland.

ETHANOL FROM SUGAR BEET, CEREALS OR WOOD WASTE

There are two likely ways in which ethanol could be used as fuel for spark-ignition engines in Ireland:

(i) Petrol-ethanol blends could be used in conventional unmodified spark-ignition engines. An EU Directive permits the use of up to 5% ethanol in blends with petrol (Commission of European Communities, 1985). This approach is widely used in the US, but has not been favoured in the EU, due to technical problems with the handling and storage of the fuel.

(ii) Blends of the ethanol derivative ETBE and petrol may also be used in unmodified engines. The 1985 Directive authorises up to 15% ETBE in blends. This has been the most favoured approach to ethanol use in the EU. A problem in Ireland would be the additional plant requirement for the conversion of ethanol to ETBE.

Total production costs have been estimated for conventional and lignocellulosic materials (Table 2). Since there are as yet no commercial ligno-cellulose plants, the cost estimates are speculative.

Table 2: Production costs of ethanol from conventional and ligno-cellulosic feedstocks

Feed-stock	Cost less by-product	Processing	Transport	Total
	Cost (cents/litre)			
Sugar beet	24	24	5	53
Wheat	22	29	1	52
Barley	22	29	1	51
Grass	18-24	25-32	7-17	50-73
Straw	20	36	5	61
Wood-chips	10-14	36	1-2	47-52

Table 2 shows a range of production costs from 47 to 73 cents/litre, depending on the feed-stock materials, feedstock price and transformation process. Even a full remission of road excise would make only the lowest-cost scenario competitive.

In spite of the apparently unfavourable economics of bio-ethanol production to date, it has become well established in the US, where production is stimulated by the need to oxygenate mineral fuels to comply with clean air legislation. Current US long-term projections are for an industry producing large volumes of bio-ethanol from low-cost by-product or residue ligno-cellulose materials at a cost approaching that of petrol. However, the technology for ligno-cellulose breakdown still has not reached a commercial stage. The long-term availability of suitable raw materials in Ireland, and the benefit of a low-value outlet for by-product ligno-cellulose materials, are not clear at this stage.

Ethanol production from sugar beet merits special consideration because of its potential impact on the existing sugar industry. Greencore has made known its interest in building a plant to produce ethanol from beet and molasses. Facilities are already in place for the organisation of crop production under contract, and for transport, reception, pre-cleaning and juice extraction; only the fermentation and distillation plant would need to be added.

Teagasc estimates the variable costs of sugar-beet production for 2002 at 1462 •/ha (O'Mahoney, 2001). At the B-quota price of about 35 •/t, a yield of 42 t/ha would be required to recoup these costs. Given that this is close to the average yield, beet production at this price might be expected to have limited attraction for growers. However, other issues, such as the avoidance of outside-quota prices in high-yield years, would also play a part in farmers' decision-making. Certainly a full removal of road excise from the ethanol added to petrol would be essential to make the project viable for grower and processor.

A bio-ethanol industry would make only a small contribution to the reduction of CO_2 emissions, as a result of the relatively large amount of energy used in processing.

The main advantages of bio-ethanol as an additive to petrol are:

(i) its oxygenating effect, leading to a reduction of CO in vehicle emissions and a reduced potential for ozone formation in the atmosphere.

(ii) its effect as an octane enhancer, as an alternative to lead compounds or MTBE.

(iii) the absence of sulphur.

(iv) the reduction of hydrocarbons in the emissions.

ELECTRICITY AND/OR HEAT PRODUCTION FROM BIOMASS CROPS AND RESIDUES

Forest and wood industry residues, cereal and rape straw, and a range of annual and perennial crops have potential as fuels which could be burned to meet local heating needs, to generate electricity, or in CHP plants. All these materials have similar problems as fuels - variable and frequently high moisture contents at harvest, combined with low energy densities. In comparison with fuels such as coal, this makes them troublesome and expensive to transport, store, handle and stoke.

Raw Materials

Forest residues: About 500,000 ha of land is afforested, and about 2 million m^3 of timber per year is harvested. A by-product is branch and treetop material, termed forest residues. Currently this is not utilised, and remains in the forest. Suitable harvesting systems would allow some forest residues to become available for energy and other uses. On some forest sites it is necessary to use the residues as brash mats for machinery traversing soft ground. On all sites the residues break down and release nutrients back to the soil.

Forest residues without leaves constitute 23 - 35% of the above ground biomass of trees. So each year over 300,000 dry tonnes of residues are left in Irish forests. The availability of forest residues depends on the type of site and harvesting method used, and the size and distribution of individual harvest areas. Coillte have estimated that 200 kt could be available for collection. Before this resource can be utilised, residue collection and transport systems are needed. More work on collection techniques, and on the costs of collection, transport and chipping, is urgently needed before commercial development can take place.

Wood industry residues: A total of about 400 kt of residues is produced by the wood processing industry each year. Of this, 100 kt is used as fuel within the wood industry. The remainder is sold for board manufacture and other uses at home and abroad. The supply of this material is starting to outstrip demand, and increasing amounts could become available for energy use if a profitable outlet could be found.

Straw: The combustion of cereal straw has been practised in Denmark at various operating scales; on-farm domestic heating units, village heating systems and central generating stations. If the moisture content is below 15%, the material stores and burns reasonably well.

Ireland produces about 1 Mt of straw. The mushroom industry requires about 100 kt. The remainder is either used on the farm or sold for animal feeding or bedding. Straw prices have always fluctuated widely, and large supplies are unlikely to be available at prices that would make its widespread use as a fuel economical.

Annual arable crops: These crops would have their best opportunity on set-aside land. The most likely possibilities are hemp and whole-crop cereals and rape. Hemp is an annual crop with potential to give a high dry matter yield at a low moisture content, and with good combustion properties. Harvesting and storage systems need further research.

Arable perennial crops: The most appropriate species for perennial energy crops in Ireland are willow and poplar managed as short-rotation forestry or the C_4 grass species, miscanthus.

Teagasc trial results show that on suitable soils short-rotation forestry is capable of yielding 7 to 11 oven-dry tonnes of biomass per hectare per annum. The midlands and south-east are most suitable for growing short-rotation forestry, though sites can be found in all parts of the country. Harvested in the winter months it has a moisture content of about 50%, at which it heats rapidly in storage in chipped form. It can be burned in simple heating units at high moisture, but it must be dried for use in gasification or CHP plants. Drying in forced ventilation systems incurs substantial capital costs. Field curing of whole felled trees increases handling and working capital costs.

Miscanthus also has attractions for this purpose given its high dry matter yields, but little is known to date about its moisture at harvest or the problems of storing/drying to meet a yearround demand. Low-cost crop establishment systems also need to be developed, and more information is needed about production costs and economics.

Biomass-to-Energy Conversion Systems

There are several levels of operation at which the use of these fuels for heat/electricity production could be considered:

Small-scale heating: Firewood remains a major biomass-energy use in Ireland. Each year approximately 140,000 dry tonnes of wood are used for domestic heating. Wood is a reasonably priced fuel, but lacks the convenience of oil or gas. There is little organisation in the production and supply of firewood, and without a big increase in fossil fuel prices there is unlikely to be major growth in the domestic market. At least one proposal is being developed at present to use wood from nearby forests for the heating of a large school. If this goes ahead, it will provide an opportunity to demonstrate the latest technology for stoking, ash removal etc. so that management can be simplified. It will also provide an opportunity for the local community to get involved in a significant local use of renewable energy.

The supply of wood pellets to the urban domestic market is being studied at present. Pellets are more compact, cleaner and have superior energy density to cut wood. They would be relatively expensive, but may find sufficient customers who would like to use a renewable fuel. However, it will take some years to develop the market to a scale that would make an Irish pelleting plant viable.

Electricity/heat production: A model for a small CHP unit, based on gasification followed by gas cleaning and combustion in an internal combustion engine has been pioneered in Northern Ireland, where two plants of this type have been built. The size of power unit could be from 100 kW to 500 kW.

The use of the internal combustion engine leads to a low efficiency of conversion to electricity. Therefore, it is of prime importance that there is a demand for the heat produced for all the time that the plant is running. Other methods of enhancing the viability of this type of project that are being explored in Northern Ireland are:

- The use of the associated short-rotation coppice area for the disposal of treated sewage effluent.
- The use as fuel of a mixture of spent mushroom compost (SMC) and wood-chips. SMC is a low-grade fuel, but with a gate fee its use in this type of plant could become attractive.

Given the need for an on-site demand for all the heat and preferably most of the electricity, the scope for replication of this technology is limited. Just as with the Northern Ireland work, it will be necessary to find ways of adding value to projects to supplement electricity as the revenue source.

Where a large on-site heat demand exists, larger CHP plants, based on conventional combustion and steam turbines may become viable. Two proposals for plants of about 5MWe capacity are being studied at present.

Electricity generation in plants over 10 MW: At this scale of operation, much higher efficiencies can be achieved with more conventional and well-proven equipment. However, as an indication of the scale of this type of operation, a 30MW plant would require an area of 20,000 ha of woodland or coppice for its supplies. The most likely scenario for the use of wood in a large plant would be to part-supply one of the peat-burning stations. This would present few technical problems, and the risks associated with a single-fuel supply would be avoided. This approach will gain momentum as peat supplies dwindle further and pressures for their conservation increase.

CONCLUSIONS

It is time we made a serious attempt to develop a number of biofuel industries in Ireland. In addition to the GHG problem and the need to improve our fuel supply security, we would be making a start on the development and use of technologies that will inevitably be needed in the future.

Since raw material is the predominant cost in all systems for the conversion of biomass to energy, stable supplies of low-cost raw materials are essential. These are most likely to be residues or wastes for which competing uses are either low-value or non-existent. In Ireland, in the immediate future the most likely materials in this category are forest and saw-milling residues for heat and electricity, tallow and waste vegetable oil as engine or heating fuels, and animal manure as a source of biogas. While each increase in fossil fuel prices brings these nearer to viability, some support is needed to get pilot projects off the ground quickly.

Biofuel industries begun with these by-product raw materials could form a platform for the introduction of energy crop production, i.e. forestry or arable fuel crops for heat/electricity, or rape-seed for liquid biofuels, as well as an additional sugar beet area for ethanol production.

In all these areas, technologies are now well established and in practical use in other EU countries. Such incentives as have been available in Ireland to date to stimulate renewable energy production have not been sufficient to stimulate the establishment of viable projects. To allow a beginning to be made, two changes are needed immediately: a reduction or remission of road excise on biofuels and an increased price for electricity from biomass. Since the size of the biomass resource is limited and no exchequer costs are incurred until the renewable energy is produced, these measures could be introduced with very little risk to the economy.

REFERENCES

Commission of European Communities (1985) Directive 85/536/EEC. Official Journal of European Communities, Dec. 12, 1985, 20-22.

Department of Environment and Local Government (2000) National Climate Change Strategy. Air/climate Section, Custom House, Dublin 1.

O'Mahony, J. (2002) Crop costs and returns 2002. Teagasc, Oak Park.

United Nations (1999) Draft Protocol to the 1979 Convention on long-range transboundary air pollution to abate acidification, eutrophication and ground level ozone. ECE/EB.AIR/1999/1. UNECE, Geneva.

Soil N Availability and Implications for N Inputs for Sugar Beet

M. Herlihy
Teagasc
Johnstown Castle Research Centre, Wexford

SUMMARY

Teagasc fertiliser policy aims to optimise rather than maximise fertiliser inputs. Use of optimum inputs maximises gross margins, enhances environmental quality and meets the demand for cross compliance for payments at farm level.

Prediction of soil nutrient availability is a prerequisite in balancing crop needs with fertiliser input. In the case of nitrogen (N), soil organic reserves may supply between 150 and perhaps 350 kg/ha annually, much of which can be taken up by the sugar beet crop. However, soil N is complex, and variable in its time and rate of release. Consequently, there are a number of constraints on the use of a soil test for N, which can be specific to different countries.

Our evaluation of six biological and eight chemical soil tests proved them inferior to a regression model derived from soil management criteria and growing-season rainfall. The N input predicted by the model was within +/- 30 kg/ha of the experimental optimum N in 42% of cases, comparable to 43% for the latest revision in the UK of their N index.

INTRODUCTION

Of the various nutrient elements, N is the main driver of crop growth and crop production, and normally provides the biggest yield-response. However, the acceptance of the need sometimes for high fertiliser-N inputs must be balanced by the recognition that increasing efficiency of N use is an important step in achieving environmental quality. Efficiency and moderation of fertiliser use has been an integral component of EU and national policy for some time, in response to expressions of the need to contain the volume of plant nutrients circulating in the ecosystem and to maintain environmental quality (CEC, 1992; OECD, 1990). Supporting this policy, national and local environmentally friendly schemes, such as REPS have been put in place.

The requirement for efficiency in fertiliser use is being emphasised in terms not only of achieving environmental quality and sustainability, but also in meeting the demand for cross compliance. The concept of cross compliance has been introduced by the EU to link minimum standards for environmental protection with payments at farm level. These actions will affect farm decisions on N inputs for sugar beet. In the case of fertiliser management, it is expected that Teagasc advice will be influential in any resulting code of good practice, and may even be involved in future regulations.

Teagasc advice aims to optimise fertiliser inputs, which maximises gross margin. It is accepted, however, that optimum inputs also enhance environmental sustainability. Ongoing developments ensure that the optimum N reflects progressively longer tillage rotations where necessary, and does not limit justifiably higher inputs for soils or rotations of low fertility. However, growers should be aware of the need to restrict any practice that would increase nitrate leaching or excessive nitrate levels in soils at the end of the growing season, such as the grazing of beet tops on free-draining soils in vulnerable zones.

SOIL NITROGEN – RELEVANCE AND AVAILABILITY

In considering the implications for fertiliser use, it is necessary to evaluate what is known qualitatively and quantitatively of the N status of our arable soils, what application this knowledge has in practical terms, and what solutions are available for improving or refining our prediction of N inputs. Field crops obtain their nutrients mainly from combinations of soil reserves and fertiliser inputs. The relative proportions can vary of course for soils of different fertility categories, and can also vary dramatically between different arable crops, particularly in the case of N. The soil-N reserves are of considerable importance in the case of sugar beet. For example, crop uptake of soil N relative to fertiliser N was shown under comparable conditions to be in the ratio of 90:10 for sugar beet, compared with 46:54 for maize (Hills *et al*., 1983). Generally, the soil component provides 80-90% of the N needs of sugar beet, although it can be much less in very low fertility soils. Although the pattern with cereals is somewhat similar early in the rotation, the soil N contribution may be only about 50% in continuous tillage. The distinction arises from the different N uptake sequences in relation to the accumulation of available soil N (Nmin) from soil reserves. This accumulation is well timed for the subsequent rapid growth of sugar beet.

The magnitude and range in the availability of N between soils has important consequences, and needs to be taken into account in optimising the total N requirement and, consequently, the prediction of the fertiliser N input. Estimation of the latter, therefore, depends on quantifying the availability of soil N for the duration of crop uptake. It is relevant to note that Irish soils contain big reserves of soil N, of which 98% or more is organic N of various degrees of complexity. Much of this is unavailable or only slowly available. It becomes available through biological processes in the form of ammonium and nitrate, *i.e.* Nmin. Typically, the quantity of total soil N in a 60 cm depth root profile of our arable soils to is of the order of 15000 kg/ha. This contrasts with the relatively small quantity of soil N absorbed annually by crops.

Because of its complex nature, the best definition of soil organic N has been provided in terms of pools of different levels of availability. These pools include microbial biomass and the active, stabilised and old N fractions, which constitute 4%, 10%, 36% and 50%, respectively, of the total organic N (Paul and Juma, 1981). The time required for 50% decomposition of these fractions is about 0.5, 1.5, 27 and 600 years, respectively. However, even the 36% that is stabilised N can provide a large continuing source of slowly available N because of its magnitude, even with a low rate of decomposition (Greenwood, 1986). It is obvious that the soil N made available for crop production is complicated, therefore, by the diverse organic sources and their different rates of release.

For tillage soils in Ireland, the active pool of labile or comparatively more available organic N has been shown to be of the order of 15% of the total N in the 0-20 cm depth (Herlihy and O'Keeffe, 1983). This greatly exceeds the annual release of Nmin. It is similar to other published estimates, however, and indicative of the reserve of organic N that may readily become available over time.

Seasonal Variation

Availability of soil N, and its build-up as Nmin, is influenced by environmental factors such as temperature and soil moisture, and by their influence on biological activity throughout the growing season. When temperature rises in spring and early summer, microbiological activity intensifies, which enhances decomposition of organic N and accumulation of Nmin. Generally, peaks in Nmin in spring and autumn, and troughs in summer, have been noted in fallow soils under controlled conditions (Herlihy, 1979), in response to temperature and moisture fluctuations. Others have suggested that most mineralisation occurs in autumn when soils are still warm and wetting up (Johnston and Jenkinson, 1989). There is a readily available pool of labile organic N from recent crop residue at that time also, and highest seasonal activity of bacteria and actinomycetes (Herlihy, 1973). (Mineralisation is the process of biological decomposition that converts organic N to ammonium, which is then nitrified to nitrate. Immobilisation is the reverse, and leads to incorporation of ammonium and nitrate, *i.e.* Nmin, into organic N). Table 1 shows, for different sampling times, the relative activity of the mineralisation process *per se*, indicative of the ability of soil to release N in the form of Nmin (Herlihy, 1979). The observed peak values may not reflect exact timing of equivalent field events, but do demonstrate the seasonal trends found with incubation of fallow soils. The timing of the maximum value is consistent with significant end-of-season release of Nmin, although high values are evident early in the season also, when soil temperature is rising.

Table 1: Net N mineralisation (mg/kg) in 10-day incubation in samples of soils stored at ambient temperature and field capacity

Soil texture*	**Sampling date****									**l.s.d.**
	06/02	**09/03**	**12/04**	**17/05**	**22/06**	**26/07**	**31/08**	**12/10**	**11/11**	**(36df, p=0.01)**
CSL	50.2	66.0	83.0	44.6	23.3	19.2	34.9	113.2	44.4	9.6
L	50.2	65.3	84.9	51.0	18.6	-26.6	31.6	83.8	50.7	9.6
Mean	50.2	65.7	83.9	47.8	20.9	-3.7	33.2	98.5	47.5	6.8

*CSL = coarse sandy loam. L = loam. **Negative values indicate immobilisation.

In field soils in Ireland, the seasonal accumulation of Nmin is well- timed in relation to development of crops such as sugar beet, where demand is delayed, with peak Nmin levels under cropping at about the end of June. In normal years, Nmin builds up in approximately linear fashion from about 75 kg N/ha in January to values in the range of 150-300 kg/ha or more at the end of June, depending on soil fertility. Maximum uptake by cereals occurs before the end of tillering so that the Nmin supply may be less accessible for these crops. Our data have shown that, even when high rainfall diminished the quantity of Nmin, it was replenished by further mineralisation at times when temperature and soil moisture were adequate.

Fluctuations in soil moisture within the range of 20-100% of field capacity have been shown to stimulate levels of Nmin that exceed the seasonal pattern observed at field capacity, *i.e.* at constant moisture content (Figure 1). This particular stimulus may arise from sporadic drying and re-wetting cycles causing rupture of N-rich microbial cells that are then easily mineralised, and from extra decomposition of some soil organic N. Such fluctuations can arise, given the periodic exposure of new surfaces during spring cultivation, and with the wetting and drying cycles that occur throughout the season. They, together with the trend in seasonal variation, demonstrate some of the challenges to the development and application of a stable predictive-test of N availability.

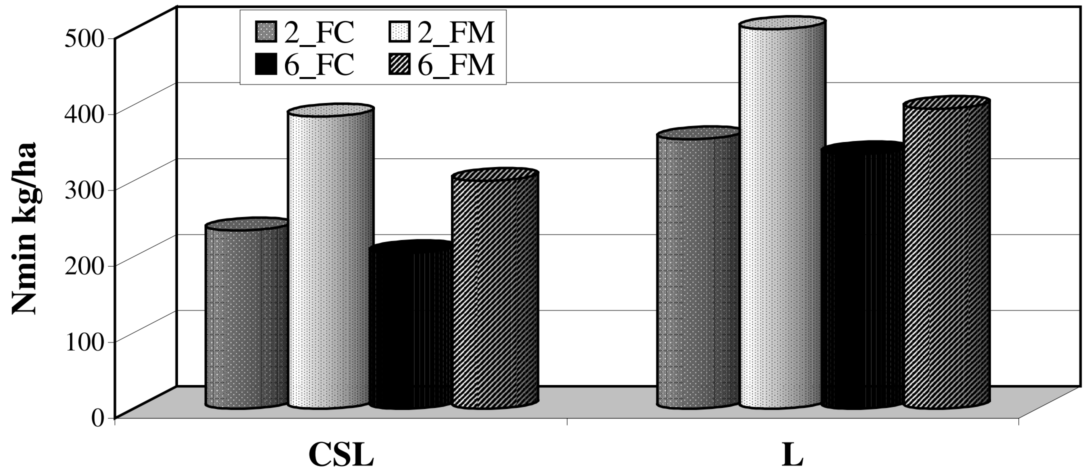

Fig. 1: Nmin in fallow soils stored at field capacity (FC) and fluctuating moisture (FM) in years 2 and 6 of tillage (adapted from Herlihy 1979). CSL = coarse sandy loam and L = loam.

Long-term trends in Nmin

The long-term trend in Nmin following ley provides a background against which to evaluate the durability of supply of soil N to crops. Figure 2 illustrates the trend in Nmin in the 0-60 cm profile at the end of June. The mean trend value of Nmin was 300 kg/ha after one year tillage, and was 85%, 78%, 69%, 60%, and 47% of the one year value after 3, 5, 10, 20 and 50 years, respectively, based on the full range of data (Herlihy and Hegarty, 2001). The expected rapid decline in the level of Nmin in the early years of tillage was evident in these results. It was also evident that there was a continued sustainability of N release, with wide variation about the mean value. Others have noted the possibility of both long and short term effects of leys on N availability (Greenwood, 1986).

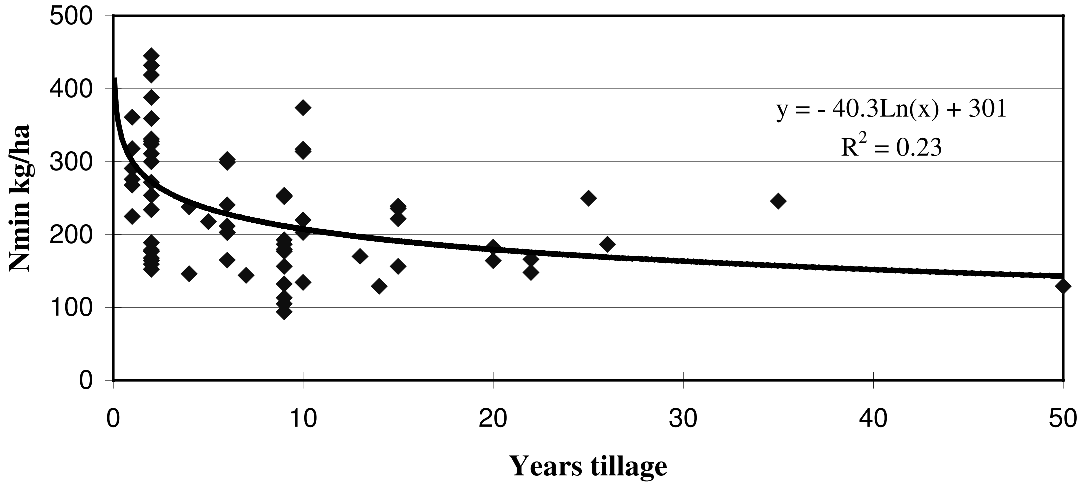

Fig. 2: Variation with number of years in tillage of Nmin in June in the 0-60 cm root profile of sugar beet.

N distribution and uptake with depth of profile

Leaching losses are minimised when N is applied during the growing season for sugar beet. Although spring/summer rainfall can displace it from the surface layer, it does not necessarily remove it outside of the root zone. Sugar beet is a deep-rooting crop that has been shown to extract isotope-labelled nitrate even from depths as great as 210 cm. Between the 107th and 138th days after emergence large increases in uptake occurred from the 180 cm and 210 cm depths (Peterson *et al., 1979*). Nitrate concentrations occurring at such depths may adversely affect sugar content, however, since absorption at these depths would occur late in the season. The data illustrate the scope for N uptake, but are of limited relevance for Irish soils, where a typical root-profile depth is of the order of 60 cm. Nonetheless, it is evident that there is active uptake of N at all depths of the root profile.

Soil tests

Although laboratory soil-tests should be the ideal for prediction of fertiliser-N inputs, there are a number of limitations to their practical application. However, precise estimates of the N that becomes available to a crop over the course of a season are complicated in a number of ways. In summary, these include (a) dependence of estimates of mineralisation on date of soil sampling (El-Haris *et al.*; 1983, Herlihy, 1979), (b) the fact that available N arises from several pools of different degrees of availability (Juma & Paul, 1984) (c) difference in mineralisation of residual organic N from crop production compared with native soil N (Smith *et al.*, 1978) and (d) variation in activities of microorganisms seasonally and in response to soil management (Badalucco *et al*., 1992; Herlihy, 1973). Other limitations arise, subsequent to crop establishment, from the interaction of weather, crop management and crop growth (Thicke *et al*., 1993), from seasonal and sporadic variation in mineralisation and its unpredictability, as noted above (Herlihy, 1979), and from gaseous losses (Greenwood, 1986). Vertical displacement of Nmin in the profile may also be an issue.

It is notable that a recent comprehensive review (Follett, 2001) concluded that there was no generally accepted predictive system for mineralisation as such. Also, as previously noted, it is ironic that within current limits the greater the knowledge of processes the more evident are the constraints on an analytically based, compared with a management based, prediction system (Herlihy, 2002). Thus, soil-N tests have rarely justified practical application. Their relevance has been questioned particularly for regions with high and variable N mineralisation in spring, which represent conditions that obtain in this country. Management-based or rotation criteria are then seen as more appropriate, especially in cropping systems that involve ley-arable farming. Soil tests may also be more useful when confined to limited regions with minimum variation in soil type and weather, and where mineralisation of organic N is low or relatively constant.

A direct profile measurement of Nmin can be, depending on its timing, a more dependable estimate of the supply of soil N, although sampling to say 60 cm in our soils would be a difficult task on a routine scale, even if justified. Our evaluation of tests on sugar-beet soils included 6 biological and 8 chemical soil tests (Herlihy and Hegarty, 2001). Of the tests, Nmin was superior to other soil tests, when combined with July-September rainfall, but inferior to the model derived from soil management criteria. The results indicated a reduced availability of end of June levels of Nmin with increasing levels of rainfall in the period of maximum crop uptake. Combinations of soil tests and management data did not improve prediction of the fertiliser-N requirement. Overall, it was concluded that the Nmin method did not justify practical application.

PREDICTING FERTILISER-N REQUIREMENTS OF SUGAR BEET

It is important that a prediction system is based on calibration with relevant agronomic data on a range of soils and soil fertility, because of the variation involved. This requires a large number of experimental sites to provide sufficient replication. Our recent systematic evaluation used a data bank of 86 field sites for which detailed results were available (Herlihy & Hegarty, 2001). The best prediction of the optimum fertiliser-N was provided by a regression equation, or model, that included the following terms: (a) years in tillage, (b) ratio of years in tillage/years in ley, which weighted the ley contribution relative to the stage of the tillage rotation and (c) rainfalls for the intervals April-June and July-September. The predicted N value was within +/- 30 kg/ha of the experimental optimum in 42% of cases, comparable to the corresponding 43% observed for the latest revision of the UK arable index (Dampney, 2000). Subsequent modification to the model (Herlihy, 2003) included an attenuation factor to reflect the change in quality of the organic N derived from ley during the course of the tillage rotation, and to accommodate convergence of different ley rotations with the progression of the tillage rotation.

The advantage of the model, as opposed to a fixed index system is that it can be applied to various combinations and extremes of soil management and rainfalls. Other variables such as soil texture, crop yield, date of sowing, temperature, solar radiation and previous fertiliser N use in ley had no significant effect on the prediction of optimum N. These have been shown by others to have inconsistent effects. Separation on a soil type basis has been found often only to separate peats from mineral soils (Archer, 1988). Also, it has been noted, for example, that build-up of soil organic N in ley depends on the annual input of organic matter, and is little affected by fertiliser N within the normal range (Greenwood, 1986; Webb and Sylvester-Bradley, 1994), contrary to its use in some index systems. It is relevant to note that the general practice is for a minimum duration in ley of five years nowadays, with N applications that do not vary by great extremes and with a mix of grazing and cutting, since silage is rotated around the farm (Crowley, 2002).

Model Application

Testing of the model indicated the wide variation in optimum N obtainable even at constant years tillage. The range at 5 years tillage, for example, was 54-125 kg N/ha for varied combinations of the ratio term and rainfalls that represented dry or wet years. Such a wide range is consistent with that observed by others (Harrison, 1995), and not unexpected in large-scale field experiments or farming practice. Two conditions are imposed in terms of the use of the model as a basis of advice for N inputs, which set upper and lower bounds on the level of N applied. A lower limit to the N input of 35 kg/ha is designated, because of possible errors at implementing very low inputs. An upper limit of 200 kg/ha is designated, because very long-term tillage in excess of 30 years only slowly declines further in its level of available N.

Tables 2-5 illustrate the optimum N inputs derived for a range of representative values of each variable. The result is a more flexible and balanced sequence of N inputs that reflect diverse requirements. Table 2 illustrates a range of inputs that contrasts with a single value of 150 kg/ha that is provided by the current index system, which classifies the same mix of variables all as index 1. Index 1 for tillage crops generally, as currently constructed, includes all soils that are in tillage five years or more. It makes no distinction for progressively longer-term tillage rotations. As a result, it may under-estimate requirements for the latter and exceed them for the early years of index 1. A specific index that had been developed for sugar beet would designate inputs of 120 kg/ha for 10 years tillage or less and 150 kg/ha for greater than 10 years, which is also less flexible than the range of values in Table 2. Table 4 illustrates the influence of 2002 rainfall for different areas and the effect compared with other years.

Table 2: Optimum N (kg/ha) for tillage/ley combinations*

Tillage (years)	Ley (years)	Optimum N
5	3	108
10	3	137
20	3	167
30	3	192
5	20	71
10	20	103
20	20	155
30	20	180

*For Rain_Apr-Jun = 200 mm & Rain_Jul-Sept = 230 mm. **All categories in this Table were previously index 1.

Table 3: Optimum N for some extreme tillage/ley combinations*

Tillage (years)	Ley years)	Optimum N (kg/ha)
30	3	192
5	3	108
5	20	71
1	20	16**

* For Rain_Apr-Jun = 200 mm & Rain_Jul-Sept = 230 mm.

** Actual N input of lower limit of 35 kg/ha is permitted here to allow for possible variation or errors at such low inputs.

Table 4: Optimum-N (kg/ha) for contrasting areas and rainfall conditions for 15 years tillage and 5 years ley

Condition	Rain Apr-Jun	Rain Jul-Sept	Optimum N
Cork Airport 2002	385	137	168
Kilkenny 2002	261	139	148
Rosslare 2002	251	89	138
Low rainfall year	150	180	136
Mean rainfall year	200	230	153

Table 5: Optimum N at 10 years tillage for a mix of low, mean and high rainfalls

Years Ley	Rain Apr-June	Rain Jul-Sept	Optimum N
5	150	180	114
5	250	280	147
10	200	230	117
10	250	280	134

Practical significance of regression model

Figure 3 illustrates the relationship between the experimental and basic (*i.e.* unmodified) model Nopt values (Herlihy and Hegarty, 2001). The very large deviation from the mean trend line for some sites is evident. However, the trend line provides a basis for calibrating fertiliser N inputs over an extended range of soil fertility categories. The scatter in the data points is not untypical. Some recognition of the wide scatter may be presumed to justify inputs that are set higher by 10-20%, or by a fixed amount of 20-30 kg N given the distribution of scatter, or by use of some calculated confidence limit, as often occurs. However, other results may indicate that, due to the latitude and imprecision of optima based on response curves, the use of the mean values already provides an accommodation of 20% or more in Nopt before severe restriction is encountered – as discussed below (Herlihy and Hegarty, 1994). Nonetheless, some latitude may be justified, given that fertiliser and other nutrient distribution in experimental plots is less variable than in large commercial field-areas. Effectively, this is achieved by the output from the modified model that is used for the revised recommendations herein (Herlihy, 2003), which also provides convergence of contrasting previous durations in ley as the tillage rotation progresses, in conformity with accepted principles. It is an advantage, in any case, that optima from response curves are used, rather than N inputs set strictly on the basis of tests of significance between treatments *(i.e.* using lsd values).

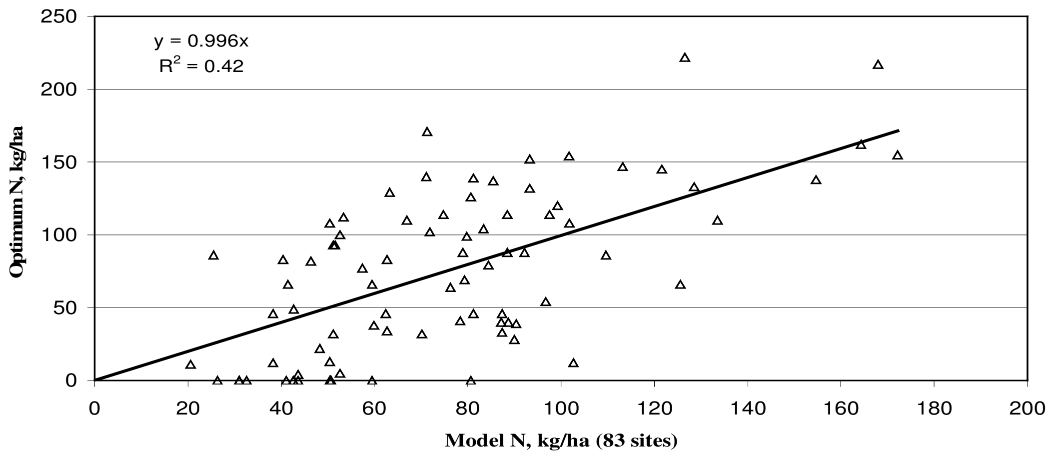

Fig. 3: Relationship between experimental optimum N and model N (unmodified), excluding three outliers.

Rainfall - Relevance and Distribution

Growing-season rainfall

In the model application, rainfall refers to the April-June and July-September totals. The practical extent and significance of the variation can be seen from the fact that, whereas the mean April-June rainfall total was 161 mm between 1978 and 1990 at Kilkenny, for example, there were three years in the range 76-96 mm and three years in the range 216-230 mm. Statistical effects of the rainfalls were demonstrated for the N inputs for sugar beet (Herlihy and Hegarty, 2001). There was a wide range in their respective values of 76-277 mm and 141-326 mm for the years represented by the data bank. The demonstrated significance of growing season rainfall for N inputs contrasts with the current assumption of availability of residual N from the previous crop and the implied relevance of winter rainfall.

April-June rainfall had a pronounced effect on vertical distribution in the 0-60 cm profile (Figure 4), but had little effect on cumulative Nmin unless excessive amounts were recorded in June. Even then, the effects on optimum N were accommodated by the model-N output used for the new recommendations. The mean depth distributions of Nmin in zero N field-plots in two normal years were 45%, 30% and 25% of the total Nmin in the 0-20, 21-40 and 41-60 cm depths, respectively, and 55%, 24% and 21% in plots treated with fertiliser N at 160 kg/ha. Comparable values in zero N plots in two wet years were 29%, 33% and 38% (Herlihy, 1983).

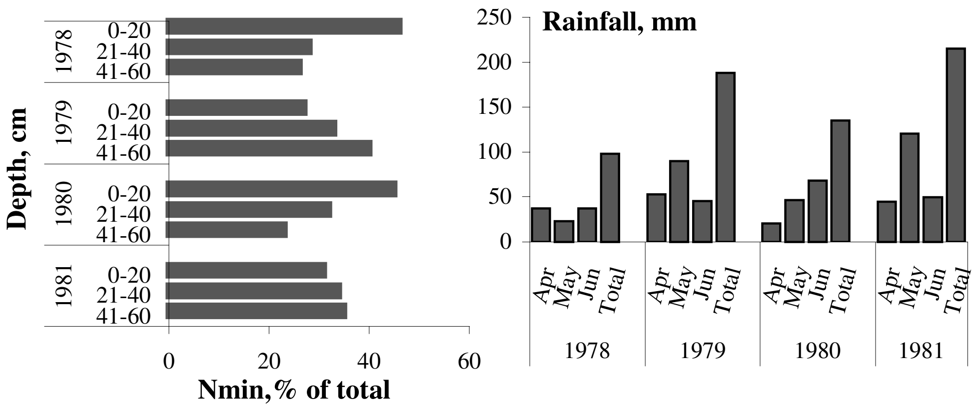

Fig. 4: Distribution of Nmin in the 0-20, 21-40 and 41-60 cm depths of the root profile of sugar beet soils as percentage of total Nmin in 0-60 cm depth.

Winter rainfall and residual effects

It may be easy to overstate the impact of the residual N for our soils and environment, given our high annual and winter rainfalls, the relatively dominant contribution of N supply from organic reserves, and the generally permeable nature of our arable soils (Herlihy and Hegarty, 2001). In the UK and Holland, winter rainfall has been used to modify N inputs on the basis of varying effects in spring of residual N from the previous cropping season. However, limits have been set on the basis that 200-250 mm November-February rainfall (van der Paauw, 1963; Eagle, 1967), or 700 mm annual rainfall (Dampney, 2000), defines an upper limit beyond which the contribution of residual N is likely to be negligible. Even in the UK, residual effects have been considered of most relevance on nitrate-retentive deep clay or silt soils, as opposed to lighter soils (MAFF, 2000). In Ireland, where field capacity is more quickly replenished, October-February rainfall is probably more relevant in terms of residual effects. Our high levels of winter rainfall suggest little likelihood of any significant level of residual effects for a succeeding crop; also, all meteorological stations representative of arable areas recorded annual rainfalls well in excess of the 700 mm limit for the period 1979-1999 (Herlihy and Hegarty, 2001).

Rainfall distribution

Global climate change and the perception of local changes in seasonal weather patterns are gaining credence. In Ireland, a statistically significant change of trend has been noted for rainfall for the months of March and April – a reduction of one third and a two-fold increase, respectively (Schulte, 2003). No change has been noted in quarterly or annual trends. Rainfall and its effect is of special interest, currently, because 2002 was much wetter than normal for many periods of time. The mean rainfall total over all regions in 2002 was 1240 mm. The comparable value was 1044 mm between 1992 and 2001. Table 6 gives an example of the quarterly and regional variation for 2002, when the April-June period was particularly excessive in the Cork region of sugar-beet growing.

Table 6: Regional variation in rainfall (mm) in 2002 (Schulte, 2003)

Months	Cork	Kilkenny	Rosslare
Jan-Mar	443	272	271
Apr-Jun	385	261	251
Jul-Sept	137	139	89
Oct-Dec	575	396	636
Year	1539	1068	1247

GENERAL ASPECTS OF N USE

Fertiliser N inputs must take account of the optimisation of yield and input costs, variation in soil nutrient supply and effects on quality. Both fertiliser N and soil N can induce significant changes in yield. However, an increased N supply diverts more energy from sugar (sucrose) storage to metabolism in growth of roots. This can result in reduced sugar concentration and increase the accumulation of amino-N compounds, which determine the extractability of sugar during processing.

Agronomic Aspects

Previous analysis showed that average responses to N (t/ha of sugar) were 1.82 and 1.37 for continuous tillage and shorter-term tillage, respectively, and between 0.18 and 0.73 and for the early stages of the tillage rotation (Herlihy, 1992). The mean difference between the amount of N needed for maximum root yield and optimum sugar yield was 52 kg/ha. On average, each 50 kg N decreased sugar concentration by 0.3% and extractability by 0.7%. Overall, the results confirmed previous observations regarding the effects of N, and showed that even where yield response was high, moderate inputs had detrimental effects on quality.

N uptake

The quantity of fertiliser N required is low in the context of uptake by the crop, because of the supply from large reserves of soil organic N. A crop uptake of 240 kg N/ha in tops plus harvested roots is adequate to produce a maximum yield of beet.

Deviation from optimum inputs

Occasionally, excessive fertiliser-N application may arise because of a combination of factors, such as lack of confidence in recommended inputs or a tendency to fertilise for maximum yield of easily identifiable physical product (storage root), as distinct from optimum yield of economic product (sugar). A recent survey has suggested that N usage for sugar beet may significantly exceed Teagasc advice (Coulter *et al*., 2002). Applying too much fertiliser, however, is uneconomic and not consistent with good farming practice. The question arises as to what tolerances are inherent in the optimum N derived from response curves or other procedures. N inputs derived from response curves can provide some latitude because of relatively flat response in the region of the optimum yield. It is interesting, therefore, to compare the relative effects of N inputs that are greater or less than the recommended optimum. Table 7 shows the percentage of each index category for which a yield loss of more than three per cent is observed with N inputs that differ from the optimum. In many cases the reductions are large – the three percent benchmark is used only as an indicator. Obviously, application of inadequate fertiliser N results in yield losses. It is also clear that inputs well in excess of the recommended optimum are wasteful, and reduce yield to a greater extent than moderate restriction of N, apart from the cost of the excess fertiliser. It can be concluded, therefore, that conservative use of fertiliser at or, within limits, even below the optimum is a viable alternative to an excessively high input policy, consistent with the observation that yields that greatly exceed the average are most likely attributable to effects of management other than fertiliser use (Silvey, 1981).

Table 7: Percentage of index category giving a sugar-yield loss of >3% compared to the optimum yield

Percentage of optimum N	N-Index			
	1	2	3	4
50%	75	48	41	12
75%	21	3	2	0
125%	0	0	0	0
150%	34	16	18	3

Fertiliser Strategies and Consequences

Fertiliser manufacture has a high cost, both in energy terms and in use of non-renewable resources. Observations from a number of sources suggest that attainment of the economic optimum N as general practice would also minimise the potential for N losses, comparable to those that occur in the absence of fertiliser N (Greenwood, 1990; Prins *et al.,* 1988; Stanford, 1973; Tinker, 1991).

Split application

Split application of N is generally considered more efficient than complete pre-plant application. In some countries, only 50-60 % of the recommended fertiliser-N is applied in a pre-plant application and disked into the soil. In agronomic terms, split dressing of N is considered essential in the UK. Irish work has shown no detrimental effect on yield, where even 160 kg N per hectare was worked into the soil in March or early April in the week or two prior to sowing. The different responses are largely due to detrimental effects on plant counts in the UK. However, a split dressing may help to maximise efficiency of N inputs, with a possible beneficial effect on the environment. In Ireland, a split between seed-bed application and top-dressing is advisable in the minority of cases where applications of fertiliser-N from all sources may exceed 150 kg/ha (Herlihy, unpublished). This lessens the depressive effect on sugar concentration and also, possibly, on plant population. Otherwise, there is not a general benefit in agronomic terms. However, a split between seed-bed and top-dressing has the potential to best manage inputs in relation to variation in early season rainfall. It provides for more efficient N use in response to excessive events, such as in 2002, rather than having the full application prior to heavy rainfall.

Placement of fertiliser

Placement of N or other nutrients for sugar beet has not been investigated, although some information is available from abroad. In Denmark, for example, fertiliser placement was done at drilling, 5-6 cm beside the row and 10 cm deep, using fertiliser coulters on the sugar beet drill. An average yield increase of 5% was obtained, equivalent to 25-30 kg N/ha under the conditions of the experiment (Steensen, 2002). Placement was most advantageous in dry seasons and with late drilling, which may indicate that it has limited application here for N. Principally, the effect was to increase root yield.

Slurry as source of N

Cattle and pig slurry can provide N for sugar beet. Teagasc information on slurry can be summarised as follows (Carton, 2003): Average cattle and pig slurry contain 6.9 and 3.2 %DM (dry matter) and 3.6 and 4.6 kg/tonne of *total* N, respectively, with considerable between-farm variation in %DM. Nutrient concentrations generally tend to increase or decrease in line with changes in %DM. Sugar beet farmers are advised to get an analysis of the slurry by a competent laboratory to provide a more accurate nutrient estimate. Table 8 shows the amount of available N (as opposed to total N) from cattle and pig slurry applied at three different times of the year, with incorporation of the manure into the soil at three different time periods following application. Because of the wide variation, and therefore the uncertainty regarding the N supply, not more than 33 tonne/ha (3000 gal/ac) should be applied (Carton, 2003). Equally, the uncertainty requires that slurry should not be used where low N inputs are necessary.

Table 8: N available from 11 t/ha (1000 gal/ac) cattle and pig slurry in relation to time of application, with incorporation into soil at three different time periods following application (Carton, 2003)

Application Period	Time lapse between application and incorporation of slurry into soil					
	Same Day		1 to 10 Days		> 10 Days	
	Cattle	Pig	Cattle	Pig	Cattle	Pig
March/April	19	22	15	21	12	21
Jan/Feb	7	16	7	11	7	11
Nov/Dec	3	7	4	7	4	6

Soil-texture implications

The model-N above makes no distinction for soil texture, which was not statistically significant for the sandy loams and loams that comprise sugar beet soils. Exceptionally, the crop may be grown on lighter loamy-sands, which have a lower N supply. As a generalisation, therefore, an additional 25 kgN/ha may be applied on such soils. Such soils usually have ≤10% clay but, for borderline cases, silt and sand composition may also need to be determined (Diamond, 2003). The Screen soil type is one such soil, although generally they are not in coastal areas. There may be sporadic occurrence in valleys, such as the Midleton valley. Sandstone soils may be erroneously termed sandy soils by some, but they contain 16-20% clay (Diamond, 2003).

End-of-season residual effects and N loss

Much of the potential for residual effects, and even N loss, lies in the deposition of N in sugar-beet tops, which generally contain of the order of 150 kg N/ha. If the tops are ploughed under in early winter much of this may be lost by leaching. If beet tops are lush and green they can add as much as 200 kg N/ha to the soil. At the other extreme, yellow or yellow-green tops may add perhaps 80 kg N/ha. It is apparent, therefore, that management of N inputs can have environmental consequences at the end of the growing season. There may be significant spatial variation in the mineralisation and immobilisation of N from sugar beet tops, with some areas immobilising for up to nine months after incorporation, because of the mix of crowns with leaves and petioles. The N in leaves and petioles is prone to rapid decomposition, which can result in substantial leaching losses before the following crop can use the nitrogen (Whitmore and Groot, 1997).

ACKNOWLEDGEMENTS

The author expresses his gratitude to B Coulter and O Carton for helpful discussion on the application of the model and on the implementation of the designated N inputs for sugar beet, and also to D McGrath, M Ryan and N Culleton; to D Brennan for assistance with data processing; to advisers and field staff of Irish Sugar for assistance in selection of field sites on which the analysis is based and to sugar beet growers for providing the sites. The data bank is derived from a project originally funded by the Tripartite Committee for Sugar Beet Research.

REFERENCES

Archer, J. 1988. Crop Nutrition and Fertiliser Use. Farming Press, Ipswich. 265p.

Badalucco, L, Grego, S, Dell'Orco, S and Nannipieri, P. 1992. Effect of liming on some chemical, biochemical and microbiological properties of acid soils under spruce (*Picea abies* L). Biology and Fertility of Soils 14: 76-83.

Carton, OT. 2003. Personal communication.

CEC. 1992. Towards Sustainability: A European Community Programme of Policy and Action in Relation to the Environment and Sustainable Development. CEC, Brussels. 98 p.

Coulter, BS, Murphy, WE, Culleton, N, Finnerty, E and Connolly, L. 2002. A survey of fertiliser use in 2000 for grassland and arable crops. End of Project Report, Teagasc, Johnstown Castle, 80p.

Crowley, J. 2002. Personal communication.

Dampney, PMR. 2000. Development and revision of national recommendations for the use of fertilisers and organic manures in England and Wales. The International Fertiliser Society, Proceedings No. 457. 38p.

Diamond, S. 2003. Personal communication.

Eagle, DJ. 1967. Effect of winter rainfall on residual nitrogen. *In* Residual Value of Applied Nutrients, MAFF Technical Bulletin 20: 145-158.

El-Haris, MK, Cochran, VL, Elliot, LF and Bezdicek, DF. 1983. Effect of tillage, cropping and fertiliser management on soil nitrogen mineralisation potential. Soil Science Society of America Journal 47: 1157-1161.

Follett, RF. 2001. Nitrogen transformation and transport processes. In "Nitrogen in the Environment: Sources, Problems and Management", ed. RF Follett and JL Hatfield. 17-44.

Greenwood, DJ. 1986. Prediction of nitrogen fertiliser needs of arable crops. In "Advances in Plant Nutrition" Vol. 2 (ed. B. Tinker and H. Lauchli), Praeger, New York. 1-61.

Greenwood, DJ. 1990. Production or productivity: the nitrate problem? Annals of Applied Biology 117: 209-231.

Harrison, R. 1995. An investigation of the relationship between soil mineral nitrogen in the autumn or spring and optimum nitrogen rate for winter cereals. Soil Use and Management. 11: 186-192.

Herlihy, M. 1973. Distribution of nitrifying and heterotrophic microorganisms in cutover peats. Soil Biology and Biochemistry 5: 621-628.

Herlihy, M. 1979. Nitrogen mineralisation in soils of varying texture, moisture and organic matter. 1: Potential and experimental values in fallow soils. Plant and Soil 53: 255-267.

Herlihy, M. 1983. Availability of soil nitrogen under arable conditions. Seminar for Tillage Crop Advisers, Carlow: 5-9.

Herlihy, M. 1992. Effects of N, P, and K on yield and quality of sugar beet. Irish Journal of Agricultural and Food Research 31:35-49.

Herlihy, M. 2002. Availability of nitrogen in arable soils – a perspective. Fertiliser Association of Ireland, Proceedings (in press).

Herlihy, M. 2003. *In* Research Report for 2002, Teagasc, Johnstown Castle Research Centre, Wexford.

Herlihy, M. and O'Keeffe WF. 1983. The contribution of soil reserves to the pool of available nitrogen in Irish soils. Proceedings, Symposium "Nitrogen and Sugarbeet", I.I.R.B., Brussels, 145-153.

Herlihy, M. and Hegarty, T. 1994. Effects of restrictions and prices of N, P, and K on fertiliser inputs and yield deficits of sugar beet. Fertiliser Research 39: 167-178.

Herlihy, M. and Hegarty, T. 2001. Prediction of nitrogen inputs for sugar beet: an evaluation of soil tests and soil management criteria in arable soils. Rural Environmental Series No. 31, Teagasc, Dublin: 34p.

Hills, FJ, Broadbent FE, and Lorenz, OA. 1983. Fertiliser nitrogen utilisation by corn, tomato and sugarbeet. Agronomy Journal 75: 423-426.

Johnston, AE and Jenkinson, DS. 1989. The nitrogen cycle in UK arable agriculture. The Fertiliser Society, Proceedings, No. 286: 24p.

Juma, NG. and Paul, EA. 1984. Mineralisable soil nitrogen: amounts and extractability ratios. Soil Science Society of America Journal 48:76-80.

MAFF. 2000. Fertiliser recommendations for agricultural and horticultural crops, 7th ed. London: The Stationery Office. 175 pp.

OECD. 1990. Recent Developments in the Integration of Agriculture and Environment Policies: An Assessment. OECD Environment Committee, Paris. 51 p.

Paul, EA and Juma, NG. 1981. Mineralisation and immobilisation of soil nitrogen by microorganisms. In "Terrestrial Nitrogen Cycles", ed. FE Clark and T Rosswall, Ecology Bulletin (Stockholm) 33:179-195.

Peterson, GA, Anderson, FN, Varvel, GE and Olson, RA. . 1979. Uptake of ^{15}N-labelled nitrate by sugar beets from depths greater than 180 cm. Agronomy Journal 71:371-372.

Prins, WH, Dilz, K and Neeteson, JJ. 1988. Current recommendations for nitrogen fertilisation within the ECC in relation to nitrate leaching. Fertiliser Society, Proceedings, London 276: 27p.

Schulte, R. 2003. Personal communication.

Silvey, V. 1981. The contribution of new wheat, barley and oat varieties to increasing yield in England and Wales, 1947-1978. J National Institute of Agricultural Botany 15: 399-412.

Smith, SJ, Chichester, FW and Kissel, DE. 1978. Residual forms of fertiliser nitrogen in field soils. Soil Science 125: 165-169.

Stanford, G. 1973. Rationale for optimum nitrogen fertilisation for corn production. Journal of Environmental Quality 2: 159-166.

Steensen, JK. 2002. Review on placement of fertiliser by drilling in Danish sugar beet growing. Proceedings 65th IIRB Congress 309-315.

Tinker, PB. 1991. Fertilisers in the environment. Fertiliser Society, Proceedings, London 302: 24p.

Thicke, FE, Russelle, MP, Hesterman, OB and Sheaffer, CC. 1993. Soil nitrogen mineralisation indexes and corn response in crop rotations. Soil Science 156: 322-335.

van der Paauw, F. 1963. Residual effect of nitrogen fertiliser on succeeding crops in a moderate marine climate. Plant and Soil 19: 324-331.

Whitmore, AP and Groot, JJR. 1997. The decomposition of sugar beet residues: mineralisation versus immobilsation in contrasting soil types. Plant and Soil 192: 237-247.

Webb, J and Sylvester-Bradley, R. 1994. Effects of fertiliser nitrogen on soil nitrogen availability after a grazed grass ley and on the response of the following cereal crops to fertiliser nitrogen. Journal of Agricultural Science (Cambridge) 122: 445-457.

Reduced Cultivations – Agronomic and Environmental Aspects

T. Fortune, T. Kennedy, B. Mitchell and B. Dunne
Teagasc
Crops Research Centre, Oak Park

SUMMARY

Pressure on cereal margins, due to lower prices and increasing costs, is creating renewed interest in reduced cultivations. Recent developments in equipment, herbicides and techniques have encouraged this interest. A major research programme on the effects of reduced cultivation on various aspects of crop production, soil changes and environmental factors, is now in progress at Oak Park. After two years' work, the initial results are promising, with grain yields on a par with plough-based cultivations; lower aphid numbers, more earthworms, fewer weeds and little increase in disease, also demonstrate positive findings. Management of the reduced cultivation system has not been any more difficult than the conventional.

INTRODUCTION

There is considerable pressure on cereal margins due to lower prices and increasing costs. Conventional seedbed preparation and sowing are relatively slow, energy demanding and expensive, especially where large areas are being worked. Reduced tillage that involves less intensive cultivation may provide a partial answer to the problem by having higher work rates and lower costs (Forristal and Fortune, 2002). Reduced cultivation is not a new technique; in the 1970s over 30% of crops grown on cereal growing land in England were established by reduced tillage but this had dropped dramatically to about 10% in the early 1990s. Reduced cultivation and direct drilling never achieved the same degree of popularity in Ireland but some cereals were sown using these techniques. The reasons for the fall off include – increasing grass weed populations, topsoil compaction, restriction on straw burning and inability to sow into trashy conditions.

Many long-term experiments which were conducted in the UK at that time demonstrated that well managed shallow cultivation or direct drilling for winter cereals usually gave yields as good as or better than ploughing where straw was either burnt or baled, and grass weeds controlled. Establishment of spring crops by reduced tillage tended to be less successful than winter crops except where soil conditions were particularly good. In those experiments in which reduced cultivation gave lower yields, greater populations of grass weeds and/or topsoil compaction or loss of surface structure were the causes (Davies and Finney, 2002).

What has changed since the 1970s which would make reduced cultivation more successful now? There have been a few developments:

1. More versatile drills capable of better seed placement and an ability to deal with trash and more difficult conditions
2. A more systematic approach to crop establishment has been developed, which uses stale shallow seedbeds, soil consolidation, rapid acting glyphosate and better timeliness.
3. Growers are more aware of the need to avoid soil compaction.
4. Better straw chopping and spreading mechanisms on combines have made it easier to cultivate and incorporate straw.

Apart from economic reasons, there is increasing pressure to adopt more sustainable cultivation systems than our traditional plough-based ones. Intensive cultivation can have a long-term damaging effect on soil structure, breaking down soil aggregates, increasing susceptibility to erosion and making seedbeds more difficult to prepare. It is also blamed for increasing soil organic matter breakdown and carbon loss to the atmosphere, as carbon dioxide. At a time when there is a lot of discussion about maintaining or improving soil quality it is opportune to look at the possible contribution that reduced cultivation could make in this area.

Before considering our experiments, the term 'reduced cultivation' should be defined. In the Oak Park trials, the procedure is similar for each of the cereal crops. After harvest the ground is quickly cultivated with a tine cultivator (1 or 2 passes) to 5-10 cm. This is followed immediately by a press or roller and the area is then left until a day or two before sowing when germinated weeds and volunteers are sprayed with a glyphosate herbicide (Sting CT). Sowing is carried out with a cultivator drill. This reduced cultivation system is more widely known as ECO till.

ONGOING EXPERIMENTS

Work on reduced cultivation was started at Oak Park in summer 2000 with preparation for a fully replicated experiment on winter wheat at Knockbeg and two split-field experiments on winter and spring barley at Oak Park. The programme has been expanded in 2001 and 2002. An outline of the entire programme is given in Table 1. The work may be divided into four areas.

- Detailed replicated experiments comparing agronomic, soil and fauna aspects of reduced cultivation with plough-based systems – winter wheat, winter barley, crop rotation.

- Observational split field areas on which some measurements, including agronomic, are made – winter barley, spring barley.

- Experiments in which the main focus is on the environmental aspects of reduced cultivation – effects on N leaching, greenhouse gas emissions, carbon sequestration etc.

- Work on mechanisation and labour costs – energy inputs, workrates, labour input and costs.

The objectives of the work are:

- To assess the relative merits of plough based and reduced cultivation systems for the production of cereals.

- To assess machinery performance, work rates and costs.

- To measure the effects of reduced cultivation on soil physical, chemical and biological conditions.

- To provide information on environmental aspects – nutrient leaching, greenhouse gas production, carbon build-up in the soil.

There is a multidisciplinary team working on various aspects of the project and the work involves cooperation with universities, institutes of technology, EPA and other Teagasc centres.

Because of the intensive measurements being made on the experiments, all the sites are located at Oak Park or Knockbeg. The experience of growers on different soil types will be used to build up a complete picture of the merits of the system.

Table 1: Reduced cultivation experiments in progress 2003

Crop and start-up	LAYOUT	Factors measured
Winter barley (continuous) August 2000	Split field (4 ha). Straw baled and removed Plough and reduced cultivation	Establishment, weeds, disease, grain yield and quality
Winter barley (continuous) August 2001	Replicated large plots 1. Plough 2. Reduced cultivation 3. Straw baled 4. Straw chopped and incorporated	Effects of cultivation and straw disposal method on aphid population and BYDV incidence, earthworm and slug numbers. (T. Kennedy)
Winter wheat (continuous) August 2000	Replicated large plots 1. Plough 2. Reduced cultivation 3. Straw baled 4. Straw chopped and incorporated	Establishment, weeds, disease, slugs, grain yield and quality. Soil strength, structure, nutrient stratification, organic matter, temperature and moisture, fauna – earthworms, beetles and microbiological factors.
Winter wheat (continuous) August 2002	Replicated small plots Reduced cultivation only	Herbicide rates and types of weed control Grain yield and quality (B. Mitchell)
Spring barley (continuous) September 2000	Split field (2 ha) Straw baled and removed Plough v reduced cultivation	Establishment, weeds, disease, grain yield and quality
Spring barley (continuous) September 2002	Reduced cultivation only	Drill effects on establishment
Spring barley (continuous) with winter cover crops Autumn 2002	Large replicated plots 1. Plough 2. Reduced cultivation 3. Cover crop 4. No cover crop	Effects of cover crop on crop performance and nitrate leaching under the different cultivation regimes (Part of larger cover crop/N leaching experiment – R. Hackett/Johnstown Castle)
Rotation experiment under reduced cultivation October 2002	Large replicated plots Reduced cultivation 1. Sugar beet 2. Winter wheat 3. Spring barley 4. Spring barley (continuous)	Feasibility of growing sugar beet in reduced cultivation rotation. Crop performance, weed control etc. for cereal and beet. Soil effects – organic matter and soil compaction etc. Pest incidence.
Spring barley Greenhouse gas/soil carbon monitoring 2002	Very large plots (12 ha, 2 replications) Plough Reduced cultivation	Carbon dioxide, nitrous oxide, methane flux. Changes in soil carbon. (Joint Trinity College/Oak Park work)
Mechanisation and labour 2000	-	Energy inputs, work rates, labour requirements. D. Forristal (Part of wider project to establish mechanisation costs on tillage farms .

RESULTS

Winter Wheat

The main part of the cultivations work is a fully replicated experiment on a clay loam soil at Knockbeg, comparing ploughing and reduced cultivation. Soil was quite wet at sowing in 2000 and establishment was very poor on the reduced cultivation plots; in autumn 2001 it was somewhat better but still significantly lower than the ploughed plots (Table 2). Straw incorporation did not affect establishment. In spite of the low establishment in 2000 there was no significant difference in yield between the treatments (Table 3). While there were fewer ears on the reduced cultivation area the ears were larger and 1000-grain weights slightly higher giving almost equal yields. Last year (2001-02) average yields were slightly higher on the reduced cultivation plots but the difference was not statistically significant. Reduced cultivation produced more grains/ear and higher 1000-grain weights (Table 4).

Table 2: Plant establishment and components of yield - winter wheat, Knockbeg, 2001-02

	Plant establishment (/m^2)		Ear numbers (/m^2)	Grains/ ear	1000-grain wt. (g)
	Count 1	Count 2			
Plough – straw	212	166	592	48	46.9
Plough + straw	219	171	550	50	47.0
Reduced cultivation + straw	158	123	548	53	51.7
Reduced cultivation – straw	169	124	480	55	50.3
s.e.d.	11.5	8.3	16.5	2.0	1.60
Significance	***	***	***	*	*

Table 3: Grain yield and quality - winter wheat, Knockbeg, 2000-01

	Plough	Reduced cultivation
Grain yield (t/ha @ 15% m.c.)	10.3	10.2
Moisture content at harvest	17.0	17.4
Hectolitre weight (kg/hl)	74.7	76.5
1000-grain weight (g)	44.8	46.9
Screenings <2mm (%)	1.9	2.0

Table 4: Grain yield and quality - winter wheat, Knockbeg, 2001-02

	Grain yield @ 15% m.c. (t/ha)	1000-grain weight (g)	Hectolitre weight (kg/hl)	Screenings < 2mm (%)
Plough – straw	9.7	46.9	77.6	1.1
Plough + straw	9.8	47.0	77.9	1.0
Reduced cultivation – straw	10.6	51.7	76.8	0.8
Reduced cultivation + straw	10.2	50.3	77.2	1.1
s.e.d.	0.61	1.60	0.71	0.09
Significance	NS	*	NS	**

Disease measurements taken in 2002 showed a greater incidence of take-all and sharp eyespot on the ploughed plots (All the treatments were sown with Latitude treated seed) (Table 5). There was some indication that straw incorporation reduced eyespot symptoms but cultivation method did not appear to influence it.

Table 5: Disease assessments – winter wheat, Knockbeg, 2001-02

	Take-all (%)	Eyespot (%)	Sharp eyespot (%)
Plough – straw	73.0	55.8	19.3
Plough + straw	70.1	39.7	26.7
Reduced cultivation – straw	52.9	51.4	2.5
Reduced cultivation + straw	52.3	42.1	7.2
	NS	NS	**

Slug numbers were monitored in Knockbeg over 6-week (Nov.-Dec.) periods in 2001 and 2002 under mats and refuge traps. The numbers collected under the refuge traps were higher than under the mats, and the overall numbers were much higher in 2002 than in 2001. In 2001 there was little or no difference in slug numbers between treatments; in 2002 while there were greater numbers of slugs overall there was a slight tendency towards more slugs on the ploughed treatments (Table 6). Incorporating straw seemed to have little effect on slug populations. There was a greater treatment effect on leaf damage; there was more slug damage on the ploughed than on the reduced cultivation plots receiving the same straw treatment (Table 7).

While numbers of slugs and leaf damage were lower on the replicated winter barley experiment the trends were similar. Slug pellets were not used on any of the sites in the reduced cultivation experiment.

Table 6: Slug numbers in refuge traps - winter wheat, Knockbeg, 2001-02

	No./trap	
	2001 13 Nov. - 18 Dec.	2002 11 Nov. - 16 Dec.
Reduced cultivation – straw	58.0	95.7
Reduced cultivation + straw	63.5	93.8
Plough – straw	66.8	130.8
Plough + straw	52.3	103.0

Table 7: Leaf damage (%) – winter wheat, Knockbeg, 2001-02 and 2002-03

	11 Jan. 2002	4 Nov. 2002
Reduced cultivation – straw	12.5	66.9
Reduced cultivation + straw	6.3	80.0
Plough – straw	32.4	80.2
Plough + straw	30.7	92.2

Aphid numbers were low in the winter wheat crop in 2001-02 with slightly fewer on the reduced cultivation treatment. Incorporating straw did not have a big effect on aphid numbers (Table 8). BYDV infection was lower on the reduced cultivation area.

Table 8: Aphid numbers and BYDV - winter wheat, Knockbeg, 2001-02

	Aphids/m^2 (7 Nov. 2001)	% tillers with BYDV (31 May 2002)
Reduced cultivation – straw	7.2	0.6
Reduced cultivation + straw	5.4	0.1
Plough – straw	9.9	2.6
Plough + straw	13.5	1.2

Earthworm populations vary with site characteristics (food availability and soil conditions), season and species. Populations are highly variable in space and time and can range from <10 to >10,000 individuals per square metre. Earthworms generally increase soil microbial activity and soil chemical fertility and enhance soil physical properties. Their numbers and activity are often used as one measure of soil quality or health, something we are likely to hear more about in the future irrespective of cultivation system.

Earthworm numbers were measured by excavating soil to 25cm and counting those in the removed soil, in both winter wheat and barley. The numbers are given in Table 9. While the numbers were somewhat higher under reduced cultivation in the wheat field they were significantly higher in the winter barley and would appear to be increasing.

Table 9: Earthworms numbers/m^3 – winter wheat, Knockbeg, 2001 and winter barley (replicated trial), Oak Park, 2002

	Winter wheat	Winter barley	
	22 Oct 01	2 May 02	25 Nov 02
Reduced cultivation – straw	352	104	456
Reduced cultivation + straw	456	280	376
Plough – straw	288	40	96
Plough + straw	336	64	192

Measurements with the shear vane and penetrometer showed significant differences in soil strength between the plough and reduced cultivation. Shear vane measurements to 40 and 120 mm showed that the shear strength at these depths was substantially higher on the reduced cultivation areas. The penetrometer measurements confirmed this with greater penetration resistance being recorded down to about 25 cm – the bottom of the plough layer (Table 10 and Fig. 1).

Table 10: Soil shear vane readings – winter wheat, Knockbeg, 2001 (kPa)

	Plough	Reduced cultivation
Depth 40mm	46.55	63.01
Depth 120mm	43.25	60.95

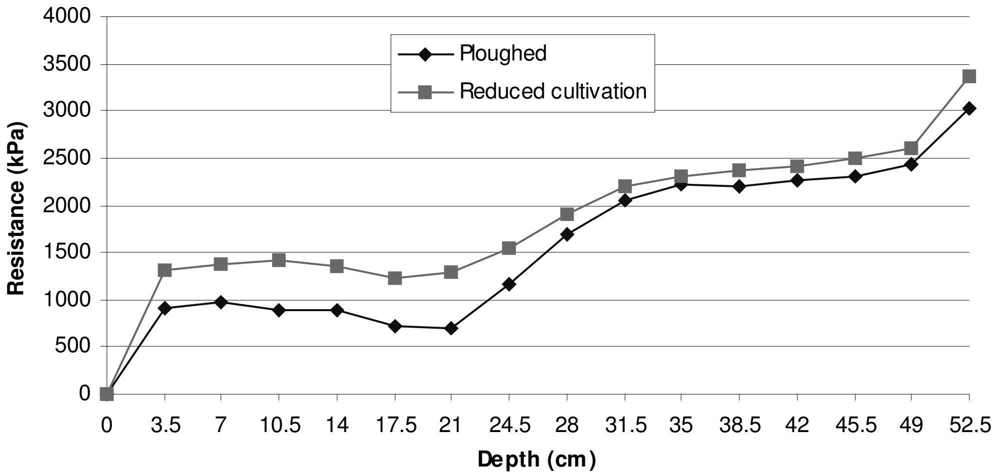

Fig. 1. Effect of cultivation treatment on cone penetration resistance at various depths

Winter Barley

The winter barley comparisons are being conducted on a free-draining, gravelly, sandy loam soil. As this trial is not replicated, the comparative results must be treated with caution. Reduced cultivations have performed well and have equalled or bettered yields from plough based cultivation (Table 11). Establishment has been inferior to ploughing but the reduced populations and ear numbers have been compensated by larger ears with more grains (Table 12).

Table 11: Reduced cultivation experiment 2001, 2002 – winter barley, Oak Park (House Field) – grain yield and quality. (Straw baled and removed from both treatments.)

	2000-01		2001-02	
	Plough	Reduced cultivation	Plough	Reduced cultivation
Grain yield (t/ha @ 15% m.c.)	8.7	8.9	6.2	7.2
Moisture at harvest (%)	15.4	16.4	16.1	14.9
Hectolitre weight (kg/hl)	64.0	64.6	59.1	62.0
1000-grain weight (g)	50.7	53.9	47.8	46.9
Screenings < 2m (%)	2.6	1.7	5.66	6.0

Table 12: Reduced cultivation experiment, 2001, 2002 – winter barley, Oak Park (House Field) – plant establishment and components of yield

	2000-01		2001-02	
	Plough	Reduced cultivation	Plough	Reduced cultivation
Plant population (plants/m^2)	-	-	256	238
Ear numbers (ears/m^2)	707	566	879	922
Grains/ear	22.7	25.3	20.3	21.1
1000-grain weight (g)	50.7	53.9	47.8	46.9

In 2000-01 and 2001-02, there was a much greater weed population on the ploughed area but in 2002-03 this was reversed. Weather after cultivation in September 2002 was very dry, resulting in a restricted germination and subsequently a poor weed kill. A flush of weeds came when the soil wetted up after the crop was sown. Meadow grass seems to be on the increase in the reduced cultivated area.

In autumn 2001, significant net blotch was measured on the winter barley. The extent and degree of infection was much worse on the reduced cultivation area (Table 13). While the main area of the trial was sprayed against net blotch, a small replicated experiment was laid down on the plough and reduced cultivation areas comparing no-fungicide and one or two sprays. There was no significant difference in yield between any of the spray treatments on either cultivation. There was also an attack of ramularia on both treatments; in the autumn this was more severe on the ploughed area but in spring the reduced cultivation treatment was more severely affected.

Table 13: Reduced cultivation experiments - winter barley, Oak Park (House Field), 2001-02– disease assessment (% plants affected)

	Net blotch[1]	Rhynchosporium	Slug damage
Plough	29.8	0.0	1.10
Reduced cultivation	72.9	3.0	2.3

[1]There was a lot more net blotch on the reduced cultivation treatment and the degree of infection on individual plants was also much greater.

On scale 0-10: Reduced cultivation = 7
Plough = 1-2

In the replicated experiments comparing the effects of plough and reduced cultivation (straw removed or incorporated) on aphid numbers and BYDV infection on winter barley, the early findings have been very interesting. In crops sown in early September with no aphicide applied there were big differences in aphid numbers and virus infection (Table 14).

Table 14: Aphid numbers and BYDV infection – winter barley, Oak Park (Road Field), 2001-02

	Aphids/m^2	Tiller BYDV infection (%)
Plough – straw	222.8	46.2
Plough + straw	278.8	42.3
Reduced cultivation – straw	144.8	13.4
Reduced cultivation + straw	46.3	6.0

There was some indication that chopping and incorporating the straw was also beneficial in reducing aphid numbers although this was not confirmed in the 2002-03 counts.

The crop yields from these experiments where two aphicides were applied, followed the same pattern as the split-field comparison, with reduced cultivation producing better yields than the plough in 2002 (Table 15).

Table 15: Reduced cultivation experiment - winter barley, Oak Park (Road Field), 2001-02 – grain yield (t/ha)

	Trial 1	Trial 2
Plough	7.2	6.5
Reduced cultivation	8.4	8.1

Spring Barley

Continuous spring barley has been grown in split-field trials in Oak Park for two years on a sandy loam soil (Clonaherk), and for one year on a loam soil (Big Bull Park). Grain yield in 2001 was lower on the reduced cultivation area than the ploughed (Table 16). In 2002 at Clonaherk there was little difference between ploughing and reduced cultivation when sown with the same drill (Vaderstad) but a lower yield was obtained after sowing with a John Deere drill (Table 17). However, on another site at Oak Park (Big Bull Park) where the Vaderstad and John Deere were compared there was no difference in yield (Table 18).

Table 16: Reduced cultivation experiment – spring barley (Clonaherk) 2001, components of yield

	Plough	Reduced cultivation	
		Autumn cultivation only	Autumn + spring cultivation
Grain yield (t/ha @ 15% m.c.)	8.3	7.9	7.9
Ears/m^2	925	997	966
Grains/ear	15.3	14.6	15.0
1000 grain weight (g)	46.1	45.3	45.3

Table 17: Reduced cultivation experiment 2002 – spring barley, Oak Park (Clonaherk)

	Plough	Reduced cultivation	
		Vaderstad	John Deere
Plant establishment (plants/m^2)	208	167	145
Ear numbers (ears/m^2)	1137	1177	1278
Grains/ear	17.1	16.2	15.1
1000 grain weight (g)	40.5	39.2	40.4
Grain yield (t/ha @ 15% m.c.)	7.7	7.9	7.0

Table 18: Reduced cultivation experiment 2002 – spring barley, Oak Park (Big Bull Park) – drill comparison, grain yield and quality

	Grain yield (t/ha @ 15% m.c.)	Hectolitre wt. (kg/hl)	1000-grain wt. (g)	Screenings (%)
Vaderstad	7.6	68.8	43.8	2.1
John Deere	7.6	68.7	43.3	2.2

The Clonaherk site was quite wet and in 2002 the crops suffered similarly from excess water and lack of oxygen on plough and reduced cultivation areas. The headlands on the reduced cultivation area appeared to suffer more in the adverse conditions and this was accompanied by an increase in meadow grass infestation.

PRACTICAL EXPERIENCES

- Winter barley has performed well over the two years on the sandy loam soil. Sowing (in September) has been into good soil conditions, giving rapid and good establishment. Reduced cultivation may add to the risk of net blotch infection but infection is not a problem every year.
- Winter wheat establishment was poorer after reduced cultivation in the first two years, but not in the third year. Crops were sown in early October in poor (varying) soil conditions but reasonable soil temperatures.
- Cultivation has been done mainly with tine cultivators but some with discs. All of these were capable of producing the basic seedbed but varied in their ability to level and deal with surface stubble/straw. It is likely that different cultivation depths will be required for different situations, such as the first couple of years, different soil types etc.
- Slugs have not been much of a problem; there was some leaf damage it was not thought to be yield reducing. Target sowing depth was about 4 cm. This deeper sowing, together with the consolidation achieved by the press wheels on the drill made it difficult for slugs to move near the seed.
- Numbers and variety of broad-leaved weeds have generally been lower on the reduced cultivation than on ploughing. The stale seedbed technique seems to work well, but it is important to have as long an interval as possible between cultivation and sowing. Meadow grass is becoming more of a problem with thinner plant stands.
- Management of the reduced cultivation crops has not proved to be any more difficult than the conventional, but most of our areas do not include headlands which may be more liable to soil compaction problems under a reduced cultivation regime.

REFERENCES

Forristal, D. and Fortune, T. (2002). New options for cereal cultivation. Teagasc National Tillage Conference Proceedings, January 2002.

Davies, D.B. and Finney, J.B. (2002). Reduced cultivation for cereals: research, development and advisory needs under changing economic circumstances. HGCA Research Review No. 48, March 2002.

Machinery, Tyres and the Soil

D. Forristal
Teagasc
Crops Research Centre, Oak Park

SUMMARY

The increased weight of machines, coupled with changes in tillage systems pose a threat to the soil structure. Damage to the soil, such as compaction, will restrict root development and access to nutrients, thereby reducing crop yield. As alleviation of compaction by deep loosening is not satisfactory, prevention of soil damage is the best approach. The selection of appropriate size tyres is important. Tyres must be chosen on the basis of the ground pressure they exert. The ground pressure required will largely depend on soil conditions, but machine weight and traffic intensity also play a role. There is a particular need to protect weaker soils and soils where minimum tillage is practiced. To achieve lower ground pressures, the tyre sizes in common use on most categories of machines will need to be increased. Increasing tyre size can be expensive and can cause transport difficulties. If the continuing trend to heavier machines continues, tyre size must be increased to protect the soil.

INTRODUCTION

Our tillage soils need to be protected. The use of increasingly heavy machines, without consideration of their impact on the soil, will result in soil structure damage. This damage will reduce crop margins. As alleviation of soil damage is not satisfactory, the aim must be to prevent it. Economies-of-scale do not favour the return of smaller lighter machines, although the effect of machine weight cannot be ignored. Similarly, altering the timing of operations or the traffic intensity is not sufficient to avoid harmful soil effects. The emphasis must be on tyre selection to help prevent damage. The use of larger tyres is not without its problems – particularly expense and vehicle width. Nevertheless, if we are to continue to use heavier machines, the use of larger, low-pressure tyres will be essential.

Why Tyres Now?

Most developments in machinery and cropping in recent years have placed increasing demands on the soil. While the combination of machinery operations and the use of wider machines have reduced traffic intensity, machine weight, continuous tillage and other factors have increased the risk of soil damage.

Heavy machinery

All machines have increased in size and capacity as users seek greater efficiency and economies-of-scale. The increase in size has not been met with a similar increase in tyre size. The Ferguson 20 and a popular tractor of today are compared in Table 1. Despite their small size, the standard 10-28 tyres of the Ferguson 20 had more than double the carrying capacity, considering the tractor's power and weight, compared to the larger 20.8R38s fitted to a modern tractor of today.

Table 1: Tyre comparison – Ferguson 20 vs JD6920s

Year	**Ferguson TE20** **1952**	**JD6920S** **2002**
Power: kW	19	119
Weight (t)	1.2	6.8
Loaded axle weight	1.2	8.0
Tyres: F	4-19	16.9R28
R	10-28	20.8R38
Tyre capacity at 0.8 bar (kg)	960	2820
Tyre capacity/weight (kg/kg)[1]	1.6 (100)	0.71 (44)
Tyre capacity/power (kg/kW)[2]	101 (100)	47.6 (47)

[1]The load carrying capacity of the rear tyres divided by the loaded axle weight

[2]The load carrying capacity of the rear tyres divided by the tractor's engine power

All categories of wheeled machines show similar trends. A typical 4-walker combine of the 1970s had a front axle load of approximately 6 t. Today's high spec 5-walker machines exert 12 to 13 tonnes on the front axle.

Continuous tillage

The move to continuous tillage in the last few decades has left the soil more susceptible to damage caused by machinery traffic. The soil is now subjected to intensive cultivation and repeated traffic passes from heavy machines, with no opportunity for recovery, such as would be available in a grass rotation. The reduction in organic matter associated with continuous tillage may also leave the soil more susceptible to the effects of traffic.

Nutrient restriction

Soil structure damage reduces the plant's ability to efficiently utilise available nutrients. Future restrictions on nutrient application will make it imperative that soil compaction is avoided to allow optimum utilisation of available nutrients.

Non-ploughing system

There is increased interest in the adoption of non-ploughing crop establishment systems, where soil cultivation is shallower and less intensive than plough-based systems. While these systems may appear to be less prone to surface compaction because of a firmer surface, they may be more sensitive to compaction than conventional plough-based systems. These systems do not have a regular deep cultivation operation (such as ploughing) to loosen the soil to plough depth.

Soil Structure Damage

The soil's structure can be described as the arrangement of soil particles and the pore space between them. A considerable part of the soil is made up of large and small pore spaces, which allow roots to grow and provide access to air, water and nutrients. If the soil structure is damaged, root development and access to nutrients are impeded. The damage caused by wheeled machinery can be described as compaction, puddling or smearing. Compaction alters the packing state of the soil particles, causing a reduction in pore space (Fig. 1). Puddling and smearing can occur in very wet conditions where the soil aggregates are broken down.

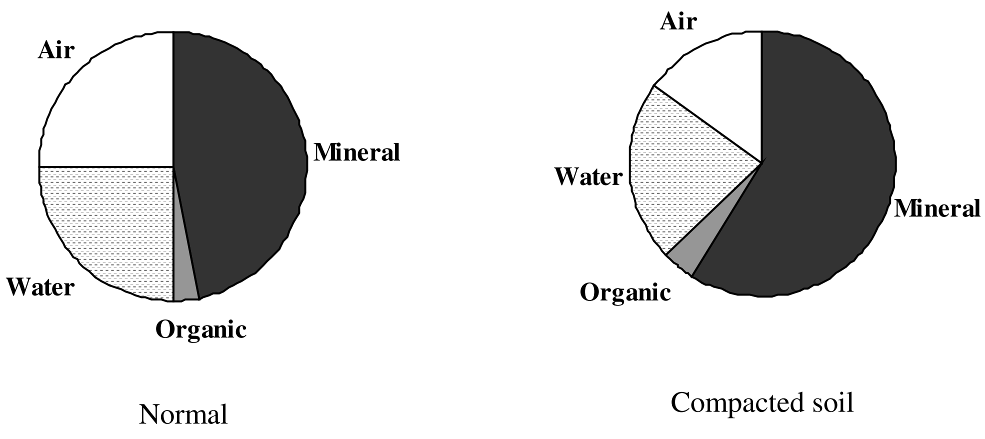

Fig. 1. Volumetric representation of soil constituents in normal and compacted soils

Compaction Research

The process and effects of soil compaction are complex and have been the subject of intense research in various countries for many years. There are many methods of measuring the effects of soil compaction including: bulk density, various soil strength measurements, water status and infiltration, and crop responses. The crop response to soil compaction is variable and influenced by many factors, including crop type, soil type, degree of compaction and moisture status during the growing season. As soil compaction is intrinsically linked with drainage and water holding capacity, the crop response is particularly dependent on factors influencing soil water status. In temperate climates, the effect of compaction on crop yield is governed by weather conditions in the growing season. A winter wheat crop planted in a compacted soil may not suffer unduly if a dry autumn is followed by a moist growing season. However, if a wet autumn is followed by a dry summer, yield could be significantly reduced. Wet autumn weather compounds the restriction on root development, on compacted soils, while a dry summer restricts the plant's ability to take up water and nutrients.

The magnitude of yield response to compaction is therefore highly variable. A review of a number of compaction experiments typically gives yield responses of the following magnitude:

Cereals	0-20 %
Maize	0-50%
Grass	8-30 %

Interestingly, the only extensive Irish research on crop response has been with the grass crop. A Teagasc trial, comparing conventional and low-ground pressure (LGP) silage harvesting traffic, showed that the use of LGP equipment increased grass yield by 9% on a dry site and 15% on an imperfectly drained site. These responses were achieved in the absence of the traffic causing surface damage. While the results of this trial do not apply to tillage crops, the magnitude of the response, in a crop not previously known for its susceptibility to compaction, is of interest.

While the duration of the effects of soil compaction is also variable, it is generally accepted that the effects will persist beyond one season.

The alleviation or removal of compaction has also been the subject of much research, particularly in the 1970s and 1980s. As compaction frequently extends below plough depth, subsoilers, or deep looseners, have been evaluated on many soils. Deep loosening has not been found to be a satisfactory remedial measure. Crop response has been variable and in many cases yields have been reduced because of the loosened soil's tendency to re-compact easily. Since the 1990s the consensus has been that compaction should be avoided. The maxim ‘prevention is better than cure’ is particularly relevant.

Factors Influencing Soil Damage

While some soils may be defined as self-compacting, compaction in this paper refers to the soil structure damage which occurs following machinery traffic. There are many interacting factors which affect this machinery-induced compaction, including:

- Soil type (texture, structure, OM content)
- Soil moisture
- Crop or crop residue present
- Level of cultivation or looseness prior to traffic
- Machine traffic, machine weight and tyre size

Soil moisture at the time of machinery traffic application is critical in determining the effect caused. Extremely dry soils will resist the compacting effect of very heavy machinery, whereas moist soils are easily damaged. Loose soils, such as those cultivated deeply, are more prone to compaction than undisturbed soils. Soils that are wet or loose at the time that traffic is being applied can be considered weak.

In most cropping situations, we have limited control over many of these factors. However, we can control the machinery operation. Machine weight, the level of traffic and, in particular, the tyre size fitted to machines can be varied.

MACHINES AND THE SOIL

The level of traffic imposed on the soil can be reduced by using wider machines and by combining field operations. Modern machine systems have reduced traffic, as the number of passes has reduced while the machine width has increased. Modern combines, for example, are frequently fitted with 6-m headers, which is double that of those used in the 1960s, resulting in an almost halving of the number of field passes. However, if the increase in machine width is accompanied by an increase in weight without appropriate tyres, the effect on soil structure can be negative.

The impact of a machine on the soil depends on the load on the wheel and the ground pressure it exerts. The effect of a wheel load on the soil is represented schematically in Fig. 2. The wheel load generates a pressure pattern which extends into the soil beneath the wheel. For a given soil condition (looseness, type, moisture), the extent and shape of this pressure pattern is determined by the load on the wheel and the contact area between the wheel and the ground. If the load on the wheel is fixed, a larger contact area (larger tyre) will reduce the ground pressure and, consequently, lessen the soil pressure.

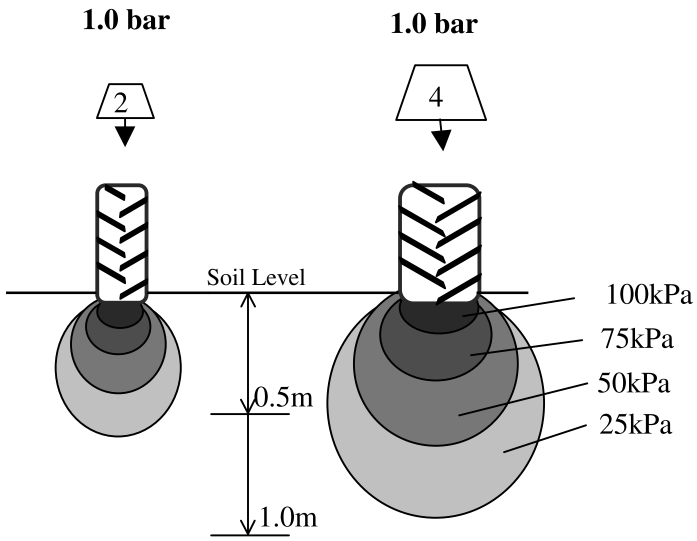

Fig. 2. Distribution of pressure stresses beneath a lightly loaded small tyre and a heavily laden large tyre exerting similar ground pressures

Theoretically, if large enough tyres are fitted, the ground pressure of any wheel load can be reduced to almost any desired value. If this was the only factor to be considered then, provided a satisfactory ground pressure was used, the weight or load on any wheel could be catered for. Independent of ground pressure, however, load does have an effect. Generally, if two wheels with different loads exert the same ground pressure, the effect of the wheel with the larger load will extend deeper into the soil. A small load only requires a small tyre/contact patch, the effect of its load is easily dissipated sideways in the soil. A very large load, however, requires a much larger tyre contact patch which effectively constrains the sideways dissipation of the force resulting in a deeper impact.

Research has shown that heavier axle loads, independent of ground pressure, can cause subsoil compaction. Deep compaction must be avoided, as it is slow and difficult to alleviate. In the 1980s, research showed that axle loads in excess of 6 tonnes were particularly harmful. Today, this load level is frequently exceeded.

While total load is important, ground pressure can reduce its impact. It is reasonable to assume that the greater the axle or wheel load, the lower the ground pressure that is required to reduce the risk of soil damage being transmitted deep into the profile. This presents a serious challenge. Fitting tyres to heavy machines to achieve the same ground pressure as smaller machines can be expensive and problematic. The need for lower ground pressures will add to these challenges.

Assessing Ground Pressure

There are many methods of estimating a tyre or track's ground pressure. One approach is to physically measure the surface area in contact with the ground. In practice, this could only be carried out on a hard surface and the effect of tyre lugs makes measurement difficult.

Ground pressure can be easily estimated from the load carrying characteristics of the tyre. The inflation pressure within a tyre can be used as a guide to its ground pressure, as it is this pressure which largely carries the load. In effect, the average ground pressure of a tyre is equal to the inflation pressure plus the carcass pressure of the tyre casing. This convention highlights the effect of tyre pressure. On a hard surface, if the inflation pressure of a tyre is doubled, its contact area is halved and its ground pressure is doubled. The relationship is less straightforward on a deformable soil where sinkage increases the contact area.

However, in both situations the **required inflation pressure** for the load being carried is a good guide to the tyre's mean ground pressure. It is an ideal figure for comparing the impact of tyres on the soil. Larger tyres hold a greater volume of air and, consequently, can operate at a lower inflation pressure and exert a lower ground pressure (Table 2).

Table 2: Tractor tyre sizes, internal sir volumes and inflation pressure requirements

Size	Internal volume (litres)	Required pressure (bar)[1]	
		2.5 t load	4 t load
16.9 R 38	411	1.4	-
18.4 R 38	574	1.0	-
20.8 R 38	698	0.6	1.6
650/65 R 38	840	0.6	1.2
800/65 R 32	1150	0.4	0.7

[1]1 bar = 14.5 psi

While average ground pressures are usually discussed, there are huge variations in the actual ground pressure beneath a tyre or a track. Pressure peaks occur beneath the tyre lugs and beneath the tyre sidewalls. On yielding soils the additional forces of the increased pressure beneath the lugs are quickly dissipated to all sides.

The type of tyre used will influence the ground pressure exerted. Stiff carcass tyres will exert greater carcass or sidewall pressure on the soil. These pressure peaks are not easily dissipated. Modern radial tractor tyres have flexible carcasses, which exert quite low sidewall forces. Additionally, manufacturers can allow these tyres operate at lower inflation pressures (resulting in greater contact areas) than stiffer tyres. Tyres designed for high inflation pressure, such as combine tyres, will exert greater ground pressure than similarly sized tractor tyres.

What Ground Pressures?

There are many interacting factors that determine the susceptibility of the soil to compaction and consequently the ground pressure required to avoid structural damage. The ground pressure and/or load limit required will vary depending on conditions. Dry stubble will support much higher ground pressure than moist, deeply cultivated soil. Consequently, it is difficult to give simple ground pressure guidelines that would cater for all situations. Tyres capable of working at inflation pressure of from 0.35 bar to 4.0 bar have been used in research trials. There have been benefits in using tyres big enough to operate at 0.35 bar in certain situations.

In the past, broad guidelines of <1.0 bar for primary cultivation (ploughing or working directly in stubble) and <0.8 bar for secondary cultivation and drilling have been used. These guidelines are not adequate for all situations. While research to date does not give us the methodology to precisely determine ground pressure, tyre sizes and total load limits for specific situations, it does give us the background to develop a pragmatic approach.

Increasing soil moisture, more intensive previous cultivation, weaker structured soils and heavier axle loads will require lower ground pressure to prevent damage. For tillage operations, tyres capable of operating at maximum inflation pressure of between 0.5 and 1.0 bar should be used.

TYRE SELECTION FOR MACHINES

Tyres perform two primary functions in agricultural machines: weight support and power transmission. The load capacity of the tyre and the ground pressure it exerts will determine its suitability for supporting a machine. Load on the tyre, contact area and other design features will influence the tyre's ability to transmit power. While this paper is focussing on the load carrying characteristics of tyres, for driven axles, power transmission must also be considered. There is rarely a serious conflict between tyre needs for reducing ground pressure and increasing traction; although there is some compromise of abilities. A wide tyre contact patch may be good for reducing ground pressure whereas a long, narrow contact patch is best for traction. Similarly, very low ground pressure will not allow high pulling forces to be developed. For the most part, however, both requirements can be satisfied.

Tyre Types and Nomenclature

Before considering the selection of tyres for various machines it is important to understand the nomenclature or size and capacity ratings of the modern tyre. A typical side-wall marking on a modern tyre may be:

600/65 R 38 157 A8 154B

600:	Tyre section–width in millimetres
65:	Aspect ratio i.e. ratio between tyre side wall height and width
R:	Radial construction
38:	Rim diameter in inches
157A8[1]:	Load index of 157 (4125kg carrying capacity) when the tyre is worked at a maximum speed of 40 km/h (A8 is the 40 km/h speed symbol)
154B[1]:	Load index of 154 (3750 kg carrying capacity) at an operating speed of 50 km/h (B is the 50 km/h speed symbol)

[1]It is important to note that a high load carrying capacity can be achieved by using a larger tyre and/or a tyre that can be used at high inflation pressures. If the latter is chosen (often the case with combines) ground pressure will also be high.

There is now an almost bewildering choice of tractor tyre sizes available with '85, '75, '70, '65 and '50 series (aspect ratio) tyre ranges available from many manufacturers. Today, there are typically 70 different sizes of tractor drive-tyres in a tyre manufacturer's range. This allows a suitable tyre to be found for almost any situation. Many factors must be considered when selecting a tyre including:

- Load carrying capacity and inflation pressure/load characteristics
- Tyre width (clearance for tyre and vehicle width)
- Tyre diameter (clearance for tyre)
- Rolling circumference (4 WD ratio, overall gearing)
- Carcass stiffness
- Tread pattern
- Make and price

To reduce ground pressure, the load and inflation pressure characteristics are most important. All tyre manufactures produce load and inflation pressure tables that allow tyres to be selected on the basis of their required inflation pressure for the load to be carried. The required inflation pressure can be used as a basis for selecting tyre size. A heavy machine will require a much larger tyre than a lighter machine, to operate at a given inflation pressure. The broad guidelines given in Table 3 are a useful starting point in the tyre selection process. In the following sections of this paper, tyre options for a number of machine categories are presented.

Table 3: Tyre ground pressure guidelines

Tyres capable of operating at inflation pressure (bar)	Machines/operations
<0.5	- Machines working on extremely weak[1] soils, e.g. ATVs, LGP spraying etc. - Heavy machines working on weak soils
0.5 – 0.8	- All machines working on cultivated soils, e.g. one-pass sowing, cultivation, rolling - Heavier machines and/or those working on weaker (wetter) soils should target the lower range (0.5 – 0.6 bar) - All minimum tillage seedbed operations - Ploughing on weaker soils
0.8 – 1.0	- Ploughing - Lighter machines working on cultivated soils in good, dry conditions - Combines working on weaker soils or heavier combines
1.0 – 1.5	- Lighter combines or all combines working in dry conditions
>1.5	- Machines fitted with tyres requiring this pressure should only have restricted access to tillage fields

[1]weak structured or weak due to moisture content of looseness

Tractor and Plough

On most farms, ploughing is still the primary cultivation operation. While the operation is carried out on uncultivated stubble, with in-furrow ploughing the plough-side tractor wheel is working in the furrow bottom. Tyres capable of working at <1.0 bar pressure should be selected. With mounted ploughs, the maximum load is placed on the rear axle when the plough is lifted at the headland (Table 4). The move towards 5-furrow mounted ploughs results in an axle load in the region of 8 t. The inflation pressure requirements for a range of tyre sizes fitted to two tractor/plough combinations are given in Table 5. As speed influences the inflation pressure requirements, 30 km/h and 40 km/h values are quoted.

Table 4: Sample tractor and plough weights: 4-furrow and 5-furrow mounted ploughs

	Tractor wt. (t)	**Plough wt. (t)**	**Rear axle load (t)**
90 kW + 4 F Rev	5.9	1.8	6.8
120 kW + 5 F Rev	6.8	2.1	8.0

Table 5: Tyre options and inflation pressures for ploughing: 4-furrow and 5-furrow mounted ploughs

	Required pressures (bar)			
	Tractor + 4 F (3.4 t)[1]		**Tractor +5 F (4.0 t)[1]**	
Tyre size	**30 km/h**	**40 km/h**	**30 km/h**	**40 km/h**
18.4R 38	1.6	-	-	-
20.8R 38	1.2	1.4	-	-
580/70 R38	1.1	1.3	-	-
600/65 R38	1.2	1.3	-	-
650/65 R38	0.9	1.0	1.2	1.4
710/70 R38	0.6	0.6	0.8	0.9

[1]rear wheel/tyre load

With a maximum tyre load of 3.4 t, even 580 or 600 mm wide tyres are not capable of working at less than 1.0 bar pressure with a 4-furrow plough. A 650 mm wide tyre is needed to operate at less than 1.0 bar. The heavier 5 furrow plough cannot be used with tyres of less than 650mm wide. Wider tyres are needed to bring pressures below 1.0 bar.

In work with the plough lowered, the tractor axle is carrying less load than at the headland but the inflation pressure is determined by the maximum load. Inflation pressures for a 30 km/h max speed are used, as this is the lowest pressure allowed for a high draught operation - lower pressures can be used at slower speeds with low draught (e.g. combines). The use of a road transport wheel on the plough would reduce the transport load at speed and allow the 30 km/h pressure figures to be used. The use of semi mounted ploughs reduces the maximum axle loads.

Generally tyre sizes fitted to ploughing tractors should be increased. Tyres up to 650mm wide can be used in the plough furrow without seriously affecting ploughing quality. Furrow openers are available to accommodate wider tyres.

Tractor and One-Pass Combinations

The need for reduced ground pressure is much greater with a combined tilling/sowing operation, as these generally operate on ploughed, loosened soil. On all soils, tyres large enough to operate at 0.8 bar inflation pressure or less should be used. On weaker or more moist soils and/or with heavier tractors, the aim should be to work at even lower pressures, e.g. tyres capable of operating at between 0.5 and 0.7 bar.

Typical weights of two combinations: the common 3 m unit and a 6 m folding-power harrow combination, are given in Table 6. A fully loaded 3 m unit typically exerts a 7 t axle load when the combination is turning on the headland. Even with a front seed tank, the rear axle load of a 6 m unit is likely to exceed 11 tonnes.

Table 6: Sample tractor and one-pass weights

	Tractor wt (t)	**One-pass wt[1] (t)**	**Rear axle load (t)**
90 kW tractor + 3m	5.9	2.5	7.2
180 kW tractor + 6m	9.0	4.6 (1.9F)[2]	11.7

[1]Including seed
[2]Front-mounted seed tank

Tyre options and required inflation pressures are given in Table 7. For the 3m unit the pressures are selected on the basis of a maximum axle load of 7.2 t in the field at 10 km/h speed and 6.4 t on the road (empty) at 40 km/h. The road demands in this situation requires higher pressures. The minimum single tyre size for this combination in any situation would be 650 mm. Larger tyres (800mm) would be better. It is worth noting that the dual wheel option is better from a ground pressure perspective. While overall width can be a problem, duals have tremendous carrying capacity.

Table 7: Tyre options and inflation pressures for 3 m and 6 m one-pass combinations

	Required pressure (bar)			
	90 kW + 3 m		180 kW + 6 m	
	Field (10 km/h, 3.6 t	Road (40 km/h, 3.2 t)	Field (10 km/h, 5.9 t)	Road (40 km/h, 5.9 t)
18.4R 38	1.4	-	-	-
18.4R 38 duals[1]	0.5	0.6	-	-
520/70R 38	1.3	1.5	-	-
600/65R 38	1.0	1.2	-	-
650/65/R38	0.8	1.0	-	-
800/65/R32	0.5	0.6	1.1	1.8
710/70 R 42	-	-	1.2	2.0
900/50 R42	-	-	1.0	1.8
1050/50 R 32	-	-	0.8	1.4
710/70 R 42 duals[1]	-	-	0.4	0.7

[1]Duals limited to 1.75 times capacity of two single tyres

The 6 m combination unit causes serious difficulties. As the load on the rear axle does not decrease on the road (seed is carried in the front) the tyre inflation pressure is determined by the road operation. Only dual wheels give a satisfactorily low pressure in these circumstances. If the speed were restricted to 10 km/h, the very wide 1050/50R32 tyres would have sufficient carrying capacity. In practice, however, to avoid tyre damage the higher road pressures would have to be used when the unit travels on the road.

The challenge presented by a 6 m combination unit is significant. The tyres required to reduce ground pressure will increase the transport width to about 3.6m (1050 mm singles) or 4.3 m (710 m duals). Without these tyres, the only option is to try and limit the damage caused by restricting turning traffic to unploughed headlands. However, this will only offer some protection.

The 6 m example questions the logic of using fully-mounted equipment on very high-powered tractors. While modern tractors have tremendous lifting capacity, and fully-mounted machines give a manoeuvrability advantage, the loading placed on the tractor rear axle is excessive. The use of semi-mounted or trailed machines reduces this loading.

Minimum Tillage

Shallower cultivation and consolidation during seedbed preparation combine to make minimum cultivated soils less prone to sinkage when subjected to machinery traffic. Because soils in this system are not subjected to annual loosening by ploughing to 200-250 mm deep, it is imperative that machinery traffic does not compact the soil. Both the weak cultivated topsoil (0-80 mm) and the complete profile are at risk from all machine operations. Traffic control measures, such as the avoidance of unnecessary traffic and not imposing traffic in moist conditions, are essential, as is the use of larger, lower pressure tyre equipment.

The primary cultivation operation is not that difficult to resolve from a ground pressure perspective, with semi-mounted or trailed equipment not placing too much load on the tractor axle. However, all tyres should be sized to operate at less than 0.8 bar pressure.

The cultivator drills used in this system, while trailed, are quite heavy and when full of seed they exert a reasonable load on the tractor rear axle when turning (Table 8). However, larger tyre options can easily cope with these weights (Table 9).

Table 8: Minimum cultivation drill: sample weights

	Tractor wt. (t)	**Drill wt. (t)**	**Rear axle load (t)**
97 kW tractor + 3 m drill	6.0	4.4	6.4
195 kW tractor + 6 m drill	9.0	7.5	9.5

Table 9: Tyre options and inflation pressure for minimum cultivation drill

	3 m unit (3.2 t/tyre)		**6 m unit (4.2 t/tyre)**
18.4 R38	1.6	620/70 R42	1.2
600/65 R38	1.1	650/85 R38	0.8
650/65 R38	0.8	710/70 R42	1.0
800/65 R32	0.5	900/50 R42	0.8

Combines

Many factors contribute to the axle load imposed by combines. In the field, the header is attached and the grain tank is loaded. On the road the tank is empty and the header is towed. Typical weights and axle loads for two combines are given in Table 10. An average modern combine weighs about 17 t with the header attached and a full grain tank. In work the front axle load would exceed 12 tonnes. On the road this loading would be substantially reduced: consequently the field operation, at less than 10 km/h, determines the tyre size and required pressure. Today's high-capacity combines are considerably heavier with larger headers and bigger grain tanks. This can result in front axle loads in excess of 18 tonnes (9t/tyre).

Table 10: Combine weights and axle loads

Combine size	Machine	Header	Grain	Total	Axle loads (t)			
	Weights (t)				In work[1]		On road[2]	
					Front	Rear	Front	Rear
5-walker (Hi spec)	10.6	1.4	5.0	17	12.8	4.3	7.0	3.7
6-walker/rotary	15.0	2.0	7.5	24.5	18.4	6.1	8.6	6.6

[1]Full grain tank + header
[2]Empty tank + trailed header

Tyre manufacturers allow tyres fitted to combines to deflect more than tractor tyres i.e. lower pressures for a given load. While combines work on uncultivated soil, the extremely high axle loads must be considered when setting ground pressure/tyre capacity targets. To cater for harvests in wetter seasons, a target of <1.0 bar for tyre inflation pressure would be desirable. Modern combines have difficulty achieving this target with the normal range of optional tyres (Table 11). Even with the usual "wide tyre" options (800/65 R32s), the high specification 5 walker machine fails to meet this target. In dry conditions this is unlikely to cause problems but during harvests where the soil is moist, compaction is likely. The largest capacity machines create greater difficulties.

Table 11: Combines: tyres + inflation pressures for full working load

Tyre options	Required pressure (bar)[1]	
	5-walker (6.4 t)	6-walker/rotary (9.25 t)
620/75 R34	2.0	3.3
650/75 R32	1.6	3.0
800/65 R32	1.2	2.0
1050/50 R32	0.8	1.5

[1]Cyclical loading 10 km/h inflation pressure rating

The tyres specified for combines are usually designed for high inflation pressure and consequently have stiffer carcasses which exert a greater ground pressure than the equivalent tractor tyre. In the past these tyres were deemed to have higher ply ratings. A 650/75 R32 tractor tyre has a load index of 159 (4395 kg) and a maximum inflation pressure of 1.9 bar at 10 km/h. The combine version of this tyre has a load index of 172 (6300kg) and can operate at inflation pressure up to 3.8 bar. At a given inflation pressure, the combine tyre is likely to be exerting more ground pressure than an equivalent tractor tyre.

Apart from the cost of the tyres, combine width restricts tyre choice in most situations. While manufacturers are striving to design high capacity machines with acceptable transport widths, greater efforts are needed The balance of weight may need to be shifted further to the rear where larger tyres can be accommodated.

Trailers

Most grain trailers must carry grain in the field and on the road. The demands placed on tyres from these two uses are considerable. Large capacity, low pressure tyres are required for the field while smaller, high pressure tyres would be much less expensive to operate at speed on the road. The standard tyres fitted to most grain trailers need to be operated at very high inflation pressures (Table 12). A considerable increase in size is needed to make a significant reduction in inflation pressure requirements and consequently ground pressure. Larger tyre options may require substantial axle and chassis alterations.

Table 12: Trailer tyre options: (5 t tandem axle trailer + 14 t load

	Required pressure (bar) 3.8 t/wheel 40 km h
15 R 22.5	4.0
18R 22.5	3.3
560/45 R 22.5	2.8
600/50R 22.5	2.0
600/55 R26.5	1.6

As the modification of a number of trailers would prove expensive, an alternative is to use a dedicated field trailer that transports grain from the combine to a conventional trailer or truck. This eliminates or restricts conventional trailer traffic in the field. This is the chaser-bin concept where a hopper shaped trailer with a front unloading auger and larger capacity tyres is used to move grain within fields. Wide section 800/65 R32 tyres are commonly fitted to chaser bins allowing an operating pressure of about 1.8 bar with a 15 t axle load.

CONCLUSIONS

- Increases in machine weight and changes in management systems pose a serious threat to soil structure

- Soil structure damage, such as compaction, will contribute to yield loss. Alleviation by loosening is not a satisfactory remedy. Prevention of damage is better than seeking a cure.

- The selection of appropriately sized tyres has a key role to play in the prevention of compaction. Increases in tyre size have not kept pace with developments in machines.

- Tyres large enough to operate at inflation pressures of from 0.5 – 1.0 bar are appropriate for most tillage operations. The lower pressures are required where heavier axle loads are used and/or where soils are weak because of cultivation or moisture content.

- A considerable increase in tyre size is needed to cater for 5-furrow fully-mounted ploughs.

- The use of very large fully-mounted implements on 200 HP+ tractors without very wide tyres or duals must be questioned.

- Modern combines pose a significant threat to the soil's structure if conditions are moist at harvest.

Tillage Farming Now and in the Future – A Farmer's Viewpoint

Lar Foley
Kinsealy Lane
Malahide
Co. Dublin

INTRODUCTION

First and foremost I would like to start by stating that there will be no statistics or figures in what I have to say this evening. I can well remember going to meetings in which figures were given on the costs of growing a crop, only to burn out the calculator later that evening trying to find out how such a grower could have such low costs or how his machinery costs were so low when mine took a degree in maths to work out. Therefore I will keep it simple and hopefully give you some of my personal thoughts, which you may agree or disagree with but which hopefully we won't fall out over.

In taking a look at the tillage industry, and in particular a farmer's view which is as relevant, and I would go so far as to say more relevant than some of the views put forward by those not engaged directly in the sector, I will draw on my own experiences of growing cereals over the last forty five years. I will briefly look at the past, where we are now and where I would like to see the future for tillage growers amidst all the pessimism and uncertainty that abounds.

THE PAST

The past speaks for itself and looking back it is often soothing to reminisce of how things used to be. However, it is also important to look at the past so as to establish exactly where we are at today and recognise that we have come a long way in cereal growing in a relatively short time period. I am over forty-five years growing cereals and can well remember a time when if you spoke of attaining the yields being achieved today by our top growers, you would be merely laughed at. Such yields back then were only a dream and would be never attainable in our lifetime, or so we thought. I remember getting yields of 2.5 tonnes per acre from wheat and being very glad of attaining such high yields.

So what technological advances brought us from the past to the present. The real technology on tillage farms that allowed yield drive forward came in the early to mid eighties with the systemic fungicides and improved herbicides. As tillage farmers we were very fortunate to have a very solid base of scientific knowledge that had been tried in practice and to An Foras Taluntais, ACOT and now Teagasc we must be grateful for imparting with this knowledge. For those of you who are around as long as I am you have only to glance backwards and this becomes blatantly obvious. As tillage farmers we are very fortunate that the men behind that innovative research, new developments and those in the advisory service bringing this valuable information to the field, were as enthusiastic in their drive to improve the lot of the Irish tillage farmer as we were in our hunger for the knowledge to lift yields and improve profits. In those days there was the classical sponge and water scenario. Tillage farmers were like sponges willing and able to soak up any amount of new technical knowledge that kept pouring like water from research.

THE PRESENT

And so we have arrived at where we are today. How to cope with the present is a far more challenging task and the key factor has to be the ability to adapt to change, be that change for the individual, agricultural advisers, tillage farmers, people in research or any other discipline. In my time as a tillage farmer we have gone through three currencies. The pounds, shilling and pence that until recently we called the old money, the punt that we now call 'Irish' and since 1st January 2001 the Euro. I believe this shows the relevance of how the world didn't stand still and if we stand still in agriculture or in cereal production, if even for a brief moment, we are doomed to go backwards. That we don't want given the time, resources and commitment that have been expended to bring us to where we are today.

Whatever about the past that we may have liked or disliked and whatever hopes we may have for the future, where we are at the present time in the tillage is entirely relevant to all gathered here today.

There are a few points that I would like to raise that impinge directly on the ability of any tillage farmer to continue to farm and grow his business with any degree of certainty.

(i) The first of these is land availability and logically leading on from this is who owns the land. We live in an area of North County Dublin and I will just give you an indication of who owns what. If I were to take a land area of three square miles, which is just about two thousand acres, it is fair to say that only ten per cent of the agricultural area within that three square miles is owned by farmers. We have to ask ourselves why this is so as I am in no doubt that the majority of the land area surrounding any major town or city in Ireland at this stage is not owned by farmers but may be managed by farmers.

Firstly we have no land policy and the question has to be asked as to why this is so. Why don't we have and why can't we have a land policy similar to what operates in any other country other than the UK. In my opinion there should be a land policy in place that would be favourable towards directing land, be that outright purchase or conacre, into the hands of trained farmers. Any person who has not got the recognised qualifications or adequate experience should not be entitled to claim any grant or subsidy of any kind. In our area we are in the situation that we have a shrinking pool of 'eligible land' that is in the hands of companies or developers, as the capital and its suburbs continue to expand outwards this is shrinking at an ever-increasing rate. Once growing houses this 'eligibility' is lost forever more.

You might ask how I would handle that. Twenty years ago I proposed a remedy. Why not make the situation for non-farmers, companies and speculative developers purchasing land zoned agricultural less attractive that it is at present. I would like to see a high rate of stamp duty of at least seventy per cent imposed on the non-farmer purchasing land zoned agricultural and then they might think twice about it. If it is still a viable proposition then by all means let them go ahead but at least favour the market towards the true farmer. If the relevant bodies such at the Department of Agriculture, Food and Rural Development, The EPA and An Taisce see the farmer as the custodian of the environment then fundamental changes are required if the land base is to be vested in our interest. It is worth noting that ninety per cent of land sold in Ireland for development is not sold by farmers, but is sold by developers who are accumulating agricultural land at a higher price than its agricultural value but are prepared to wait in anticipation of rezoning. The situation has got progressively worse over the last four years as the Celtic Tiger roared throughout the country. If you just take a look at your nearest town over that time you will find that land that came to the market ended up with a developer either on a long-term option or straight purchase.

(ii) Secondly is the whole area the cost of land that is available on the conacre system. We must look at the total costs coming back after having taken an extra field or farm and let each grower do his or her own sums rather than having a set figure of what you can or should be paying. I wouldn't dare tell any farmer that he was paying too much for conacre and each grower has to know his or her own ceiling for each field. The cost that you or I can afford to pay is relevant to the net result achieved. I am very conscious of setting the scene regarding the cost of land for our young farmers going into the future and there will be a breaking point when you just have to walk away from conacre that is too dear. It may not be the easiest thing to do but the more of us that do just that, the more realistic the market place will become as regards renting land at an affordable price.

This in particular manifests itself in Fingal where over the last four years we would have lost no less than three thousand acres of eligible cereal land in the Swords, Donabate, Portrane, Malahide, Baldoyle area. This invariably is also happening to a lesser extent in other areas and its not something that needs to be proved. Just wait long enough and it becomes a reality, the land is gone. This leads on to the Fischler proposals in which there would no longer be the differentiation between 'eligible and 'non-eligible' land which at the moment seems to be the only means by which we can maintain our cereal acreage, not even mention increasing scale. If our base area of eligible land in Fingal continues to be eroded as has happened inside the last five years, I must ask the question, 'Are we to continue in cereal farming and can somebody in authority tell us how it can be done?'

(iii) The big one and the most important is the price for grain. On that score one must ask why the tillage industry cannot lay down a marker for grain prices in the early part of the cropping year.

There is a great need for co-operation between the IFA, Teagasc, the millers, feed compounders and the grain traders. Its unfortunate that any consultation doesn't take place until July or August instead of the previous November or December. We are the only industry that does not have a minimum price for our product and most years this is not established until a number of weeks after the harvest have passed.

Consequently as commercial grain growers we have to commit a level of inputs into the industry irrespective of price at the end. Wouldn't it be great to know by the end of January what the minimum price for grain in the coming harvest would be? Then we could all work with our budgeted returns and tailor inputs so as to leave a margin rather than incurring a level of expenditure that will leave a negative margin.

There are a number of stakeholders in the industry who have a duty to put such a system in place if cereal growers are to be able to plan and stay committed to the industry. The farming organisations, millers, feed compounders, co-ops and grain traders have a role to play and for our sake don't be waiting for the harvest to start discussions.

At least if we had a guaranteed minimum price, it would allow decisions to be made before money was lost. If it seemed too low for some to leave a margin, then a decision not to grow could be taken. If leaving a middling margin, inputs could be tailored accordingly, and if leaving a good margin then increasing scale or output could be justified. But it is surely better to know this before committing to growing the crop rather than when finalising the merchant credit bill in November. If we just look at the last two years, in 2002 the price received in Euro was the same as that received in punts in 2001. In any mans language that's a twenty one percent drop in price.

I believe that if we had a minimum price, that we just may get more Irish livestock farmers to purchase a greater quantity of home grown cereals where they had knowledge of where grain prices would lay in the coming harvest. Most livestock farmers have the ability to store forty to fifty tonnes of grain and if we can get the livestock farmer to commit to more Irish grain, by being able to forward buy at a guideline price, we may be able to displace some of the imported feed ingredients. This can only benefit the Irish farmer, rather that the farmer in Ohio or the West Coast of America who are benefiting from our import of their feed ingredients.

Clearly there is a lack of co-ordination and co-operation within the many strands of the tillage industry, and I would like to see Teagasc as having a central and independent role in any co-ordination body that will hopefully be established sooner rather than later.

(iv) Finally there is the whole area of costs of production. No longer will any nation or community attain its goal through bullying or intimidation. The way forward is through dialogue. We have to be prepared to compromise, for the want of a better word, and some may ask how much more can farmers compromise. We have been through crises before and have come through, and I feel we are at the bottom of the current down turn. Land availability at the right cost will be a key factor in the upward turn of events.

THE FUTURE

Trying to look forward to where we are going, there is no doubt but that the tillage industry is going to undergo change. Invariably we will end up with a smaller number of growers producing the same amount of grain as long as the National Base Area remains, since this is the only means of expansion. In Dublin 292 growers claimed arable aid in 2002 having an average claim of 51 hectares. This is in contrast to Carlow with 705 applicants having an average claim of 25 hectares.

So How Do We Cope with the Need to Get Bigger to Survive?

With steering from Teagasc I can see where a small number of farmers, two, three maybe four would combine all their resources together, land, machinery and labour. The combined, would be farmed as one unit, and which would allow for greater economies of scale to be availed of.

Bulk purchase of inputs by a number of individuals coming together or by discussion groups. This may be only for a selected number of inputs, say seed and fertiliser or maybe for all inputs. It needs a lot of organisation but I am in no doubt, where properly managed, the benefits are enormous.

Bulk sale and organised sale of grain. The ability to store grain and feed the market in an orderly manner rather that selling all produce directly off the combine, will become a greater necessity as production units increase in size.

Group co-operation across the whole industry. If ever there has been a word bandied about over the last fifteen years, its transparency and what we need in the future if we are to have a viable tillage industry that our children will aspire to as a means of providing them with a viable livelihood.

CONCLUSION

Greater co-operation, commitment, understanding and transparency by all stakeholders in the tillage industry are necessary for the survival of Irish tillage farming as we move through the twenty- second century.