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Overcoming the Spotting Disorder and Fungicide use in Spring Barley

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INTRODUCTION

Spring barley production is an important economic activity on Irish cereal farms supplying the raw material for both the home and export malting trade as well as for the feed grain sector. While Ireland has a justifiable reputation for the production of high quality malting barley the introduction of modern dual purpose varieties (suitable for both feed or malting) has in the past opened up another market opportunity to those growers who traditionally supplied feed grains. This presented a challenge, as there were particular concerns about specific aspects of quality, particularly relating to increased grain proteins, germinative energy, capacity and varietal purity. Intensive research carried out at Oak Park Research Centre in the late '80’s and early '90’s produced clear guidelines as to the most appropriate husbandry practices to be followed in order for growers to obtain maximum returns.

However, since 1997 Irish spring barley growers have being trying to cope with a new problem not experienced before in the form of a leaf disorder, which causes brown spotting of the upper leaf surfaces of a range of varieties. This phenomenon was severe on many crops particularly in 1998, and has made the growing of high yielding crops of spring barley increasingly difficult. Trial results from Oak Park in 1998 indicated clearly that some varieties were more susceptible than others. The 1998 trial results pinpointed particular new fungicides which greatly reduced and delayed the onset of the typical symptoms, with the strobilurin fungicides giving better control of this phenomenon than non-strobilurin fungicides. At the same time the products gave very good control of conventional barley diseases in addition to yield enhancement benefits. In 1999 research was intensified at Oak Park Research Centre so as to:

1. Identify the agent or agents causing leaf necrotic spotting in spring barley.
2. Determine the effect of the necrotic spotting on yield.
3. Determine the relative susceptibility of barley varieties to spotting and their yield response to fungicide application.
4. Identify fungicides and their relative efficacy for the control of spotting.
5. To study fungicide strategies to give effective control of the phenomenon.

In this paper the main findings from field trials carried out at Oak Park on leaf spotting and its control in 1999 are presented, and strategies for maximise returns from fungicide use in spring barley are outlined.

RESULTS AND DISCUSSION

Causal Agent of Leaf Spotting

A complex of spots was observed in all varieties under trial. These spots were largely confined to the upper surfaces of the flag leaf (leaf 1) and the next lowest leaf (leaf 2). Well defined spots were also present on awns and the upper leaf sheath.

While not conclusive it is likely that the majority of spots which were a brown black colour were caused by the Fungus *Ramularia collo-cygni*. Spots on awns and the upper leaf sheath are also attributed to Ramularia. These tentative conclusions are based on work by Dr. E. O' Sullivan and colleagues in Oak Park who found *Ramularia* freely sporulating on the under side of the upper leaves of barley which had a large number of spots on the upper surfaces of the leaves.

Other spots which occurred on the leaves in small numbers attributed to varietal traits, spot blotch (*Drechlera tres f. maculata*) and mildew hypersensitivity.

It is also possible that light (alone or interacting with disease) was involved in producing the spotting disease.

Varieties and Necrotic Spotting

Varieties differed in their susceptibility to the leaf necrotic spotting. The varietal effect on the incidence of leaf spotting on unsprayed plots is illustrated in Figure 1, with Century, Cooper, being most susceptible while Laird, Fractal, Lambda and Lux were the most resistant. Varieties such as Crusadier, Optic, Canasta and Henni were intermediate. Ranking of varieties with confidence is difficult because the leaf spots can vary in intensity and form or shape and colour. These characteristics vary with variety and are probably influenced by environmental and fungal spore load.

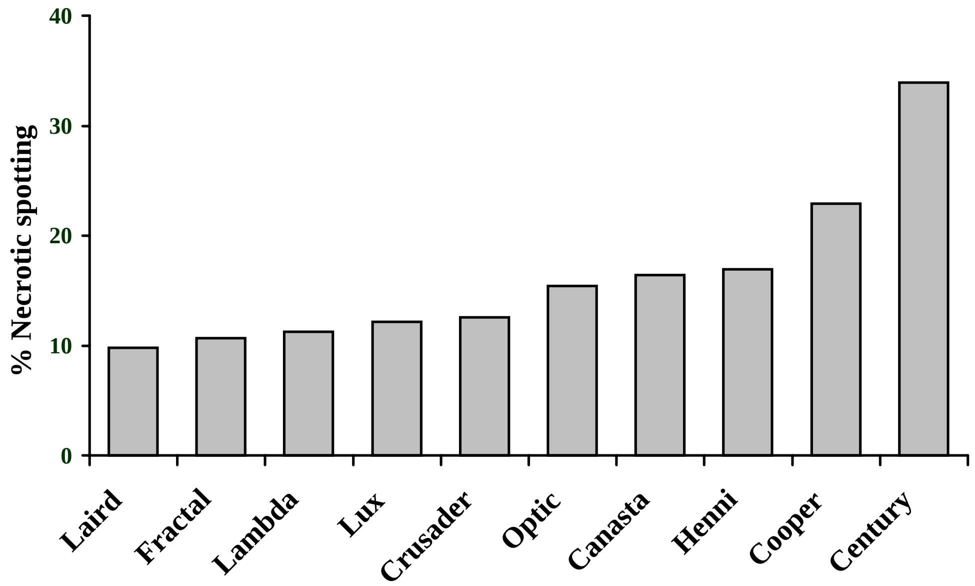

Fig: 1: Varietal susceptibility to leaf spotting

Effect of Necrotic Spotting on Yield

Trials were designed to measure the yield response to the newer strobilurin fungicides compared to the older triazole types over a range of cultivars. The main objective was to investigate leaf spotting control and yield responses to strobilurin and triazole various fungicides programmes. One particular trial investigated the disease control (including necrotic spotting) and yield responses of the two contrasting fungicide programmes on a range of spring barley varieties. The results which are contained in Table 1, Figure 1 indicate that the fungicides significantly increased grain yield with the strobilurin fungicides giving the highest yield although the magnitude of the response varied with cultivar. As the level of traditional spring barley diseases were very low in Oak Park trials in 1999 it is suggested that the control of necrotic spotting accounted for most of the yield response obtained.

Table 1: Effect of Variety X Fungicide Programme on Grain Yield - Oak Park 1999

Variety	Unsprayed	Triazole	Strobilirun	Mean
Fractal	8.18	8.91	8.97	**8.68**
Lambda	8.01	8.64	8.89	**8.51**
Laird	8.00	8.05	8.13	**8.06**
Crusader	7.87	8.37	8.49	**8.24**
Canasta	8.15	8.75	8.96	**8.62**
Optic	8.18	9.26	9.61	**9.01**
Century	7.99	8.66	9.32	**8.65**
Lux	8.60	9.45	9.78	**9.27**
Henni	7.56	8.23	8.58	**8.12**
Cooper	7.11	8.76	8.87	**8.24**
Mean	**7.98**	**8.71**	**8.96**	**8.54**

Variety x fungicide LSD (5%) = 0.38

Yield response to fungicide application was greater in varieties which showed higher susceptibilities to leaf necrosis, e.g. Laird, Crusader and Cooper which would be regarded as resistant intermediate and susceptible to leaf necrosis giving average yield responses to fungicide of 0.09, 0.56 and 1.7 t/ha, respectively, (Figure 2).

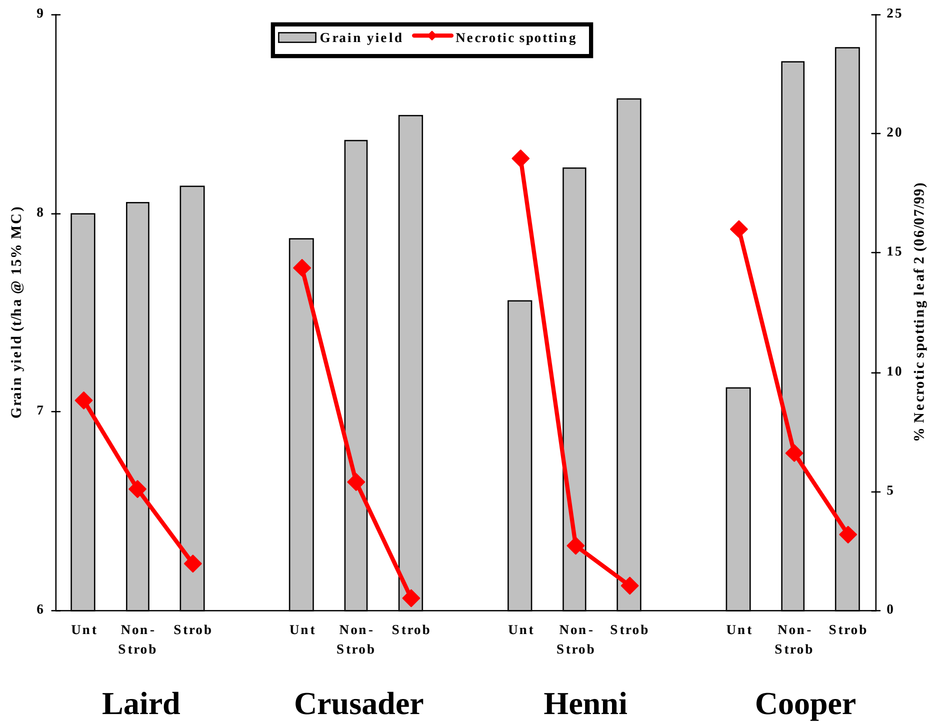

Fig. 2: Varietal response to fungicide 1999

Control of Necrotic Spotting

Fungicide type

The effect of a one-spray fungicide application (full rates) using a range of fungicides on grain yield and % necrotic spotting can be seen from data presented in Figure 3. All fungicides significantly increased grain yield and reduced necrotic spotting levels. In general strobilurin fungicides gave higher yields and lower levels of spotting than non-strobilurin fungicides. Allegro gave better performance than Amistar, Amistar Pro or Sphere.

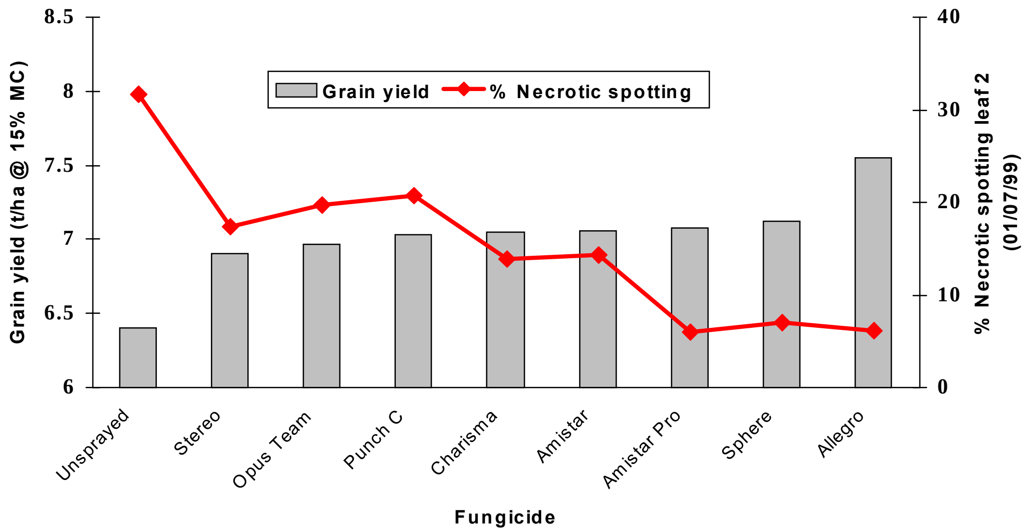

Fig. 3: Effect of fungicide (full rates) on grain yield and % necrosis 1999

Fungicide timing

The critical importance of the effect of fungicide timing on grain yield in the reducing spotting and maintaining green leaf area is demonstrated from data presented in Figures 2 and 3.

The data presented emphasises the importance of a G.S. 39 application in the reduction of spotting. A single spray applied at G.S. 30 seems too early, and 45 and onwards, too late. Splitting the dose in either two or three applications is no more effective than a single application at G.S. 39. However a split application at G.S. 30 and 45 was less effective than a single application at G.S. 39 and other split applications that received some fungicide at the critical 39 stage of growth.

The application of strobilurin fungicides at this stage of growth gave optimum control of spotting, effective control of other barley diseases and maximised it's yield enhancement properties.

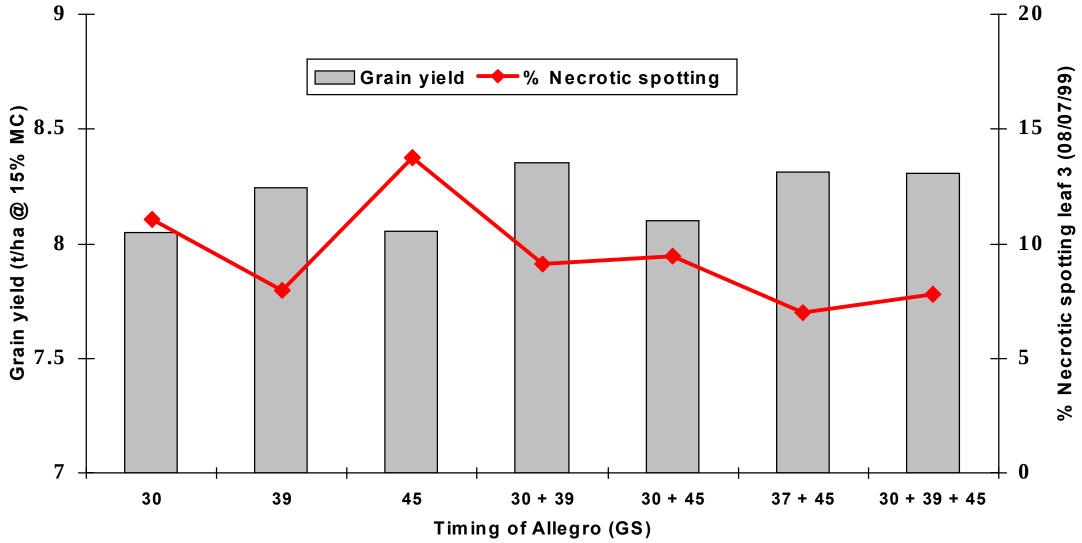

Fig. 4: Effects of Allegro (1.0 l/ha) timing on grain yield and necrotic spotting

The effect of timing of fungicide on yield and necrotic spotting is reflected in green leaf retention as presented in Figure 5.

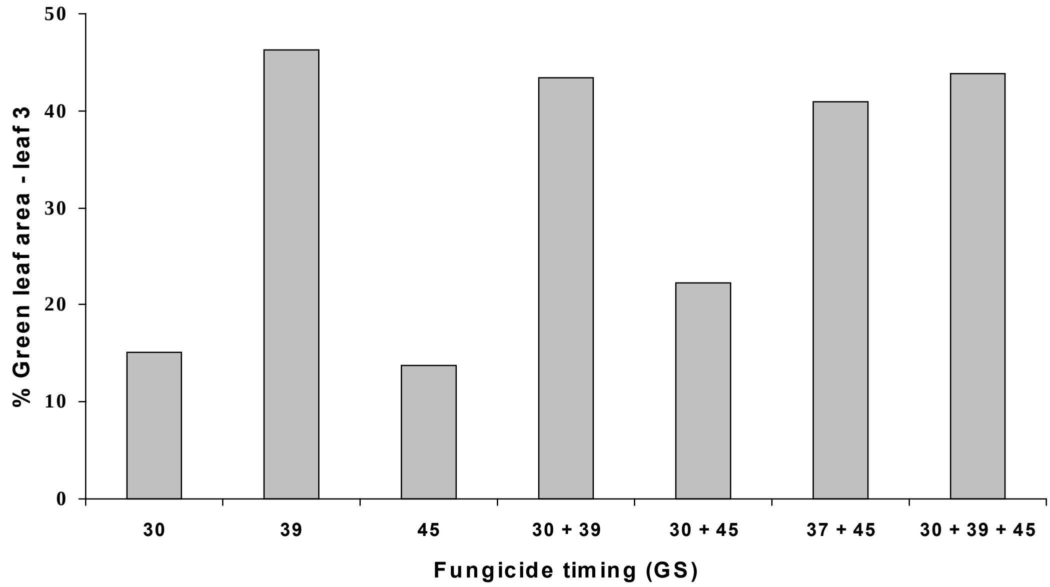

Fig. 5: Fungicide timing effects on green leaf area

Fungicide spray frequency

The results of experiments comparing one, two and three applications in terms of grain yield, reduction of spotting and green leaf retention are contained in Table 2. The best results were obtained with two and three split applications, which were significantly better that one application (one application applied at G.S. 33-37). There was no significant difference between two and three applications either in yield, % necrotic spotting or green leaf area.

Table 2: Effect of fungicide splitting on grain yield, necrotic spotting and green leaf area

	Grain Yield	**Necrotic Spotting leaf 2**	**Green Leaf Area leaf 2**
One application	7.39	13.10	17.77
Two applications	7.78	6.97	31.59
Three applications	7.80	6.00	33.27
Untreated	7.21	24.80	8.38

Fungicide programmes

The performance of eleven two-spray fungicide programmes was evaluated on the variety Cooper. Six of the programmes had the same non-strobilurin treatment at the first application (G.S. 30) to study the performance of a range of strobilurin and non-strobilurin fungicides when applied as the second spray, (G.S. 39). Non-strobilurins were substituted by strobilurin fungicides and a mildewside (Fortress Duo) as the first spray in the remaining programmes. Trial treatments and their effect on yield necrotic spotting and grain quality are presented in Table 3.

Table 3: Treatments - Fungicide Trials, Oak Park, 1999

Treatment No.	T_1 Application (G.S. 30)	T_2 Application (G.S. 39)	Grain yield (t/ha)	% Necrotic spotting Leaf 2 (12/07/99)	Hectolitre weight (kg/hl)	Screenings < 2.2 mm (%)	1000 grain wt. (g)
					Grain quality		
1	Allegro (0.3 l/ha)	Allegro (0.7 l/ha)	7.95	4.40	66.70	3.77	39.90
2	Amistar Pro (0.6 l/ha)	Amistar (0.7 l/ha)	8.08	6.58	66.53	3.79	39.89
3	Allegro (0.3 l/ha)	Amistar (0.7 l/ha)	8.05	7.75	66.72	3.73	39.32
4	Fortress Duo (1.0 l/ha)	Amistar (0.7 l/ha)	8.01	7.92	66.97	4.24	38.78
5	Sanction (0.3 l/ha) + Corbel (0.5 l/ha)	Allegro (0.7 l/ha)	7.93	5.27	66.68	4.10	39.77
6	Sanction (0.3 l/ha) + Corbel (0.5 l/ha)	Amistar (0.7 l/ha)	7.99	9.67	67.00	3.51	39.48
7	Sanction (0.3 l/ha) + Corbel (0.5 l/ha)	Rombus (0.7 l/ha)	7.84	7.70	66.75	4.42	39.51
8	Sanction (0.3 l/ha) + Corbel (0.5 l/ha)	Charisma (1.5 l/ha)	7.62	10.53	66.87	4.86	38.77
9	Sanction (0.3 l/ha) + Corbel (0.5 l/ha)	Opus Team (1.5 l/ha)	7.49	9.77	66.88	5.59	38.24
10	Sanction (0.3 l/ha) + Corbel (0.5 l/ha)	Cogito (0.5 l/ha)	7.54	9.85	66.78	5.21	38.25
11	Unsprayed	Unsprayed		25.53	65.17	11.49	34.51
L.S. D. (5%)			**0.24**	**4.88**	**0.61**	**1.41**	**1.15**

T_1 and T_2 sprays were applied at G.S.'s 30 and 39, respectively. All fungicide programmes significantly increased grain yield (Tables 2 and 4). Again, as in previous trials, conventional barley diseases were at a very low level, it was considered that they contributed little to loss of yield. Therefore, the control of leaf necrosis with fungicide application accounted for much of the yield response. All fungicide programmes significantly reduced the level of necrotic spotting.

Where fungicide T_1 spray was kept constant, strobilurin fungicides gave better performance in terms of yield response when applied as the second spray (Tables 2 and 3). This was due to a combination of (1) greater reduction in spotting levels (although not always significantly) and (2) the yield enhancement or the "Strob" effect. No significant differences were detected between strobilurin fungicides in terms of grain yield

Using a strobilurin fungicide as the first spray had no advantage in terms of yield response or for the control of necrotic spotting.

Fungicides significantly increased the 1000-grain weight with the strobilurins tending to give higher mean grain weights than non-strobilurins when applied as the second spray. Fungicide application increased hectolitre weight and significantly reduced screenings with little difference in these parameters between fungicide programmes (Table 3).

Fungicide costs

A fungicide cost benefit trial on the variety Century, showed no significant difference between programmes costing £30 or £50/ha. This applied to both non-strobilurin and strobilurin fungicide chemistry, regardless of whether they were applied in one, two or three spray applications (Table 4).

Table 4: Fungicide cost effects on grain yield necrotic spotting and green leaf area

	Grain Yield	**Necrotic Spotting % leaf 2**	**Green Leaf Area % leaf 2**
£30/ha	7.71	9.34	27
£50/ha	7.60	8.03	27
Untreated	7.21	24.80	8

Effect of Nitrogen and Fungicide on Necrotic Spotting

In a trial comparing 75,100, 125, and 150 kg/ha of N a yield response was obtained up to 125 kg/ha although there was no significant yield response above 100 kg/ha. (Table 5). There was an indication that strobilurin fungicides gave a higher yield at the highest nitrogen level of 150 kg/ha than conventional fungicide chemistry, but this was not at a significant level. The effect on grain nitrogen was dramatic with just an extra 25 kg/ha of N increasing the grain protein content by over 1%. However, protein content tended to be lower with strobilurin fungicides probably due to a dilution effect. There was no evidence that nitrogen had any effect on the % leaf necrosis.

Table 5: Nitrogen and fungicide interaction on grain yield, % necrosis, green leaf area and protein %.

N (kg/ha)	Grain yield t(ha)	% Necrosis leaf 2	Green leaf area (%) leaf 2	Protein %
75 (Non-strob)	6.17	5.50	20.9	9.58
100 (Non-strob)	6.58	4.70	25.7	10.18
125 (Non-strob)	6.85	4.60	26.0	11.25
150 (Non-strob)	6.84	4.60	27.0	12.29
150 (Strob)	7.10	1.70	51.0	11.97
L.S.D %	0.33	1.70	16.0	0.36

CONCLUSIONS

- Necrotic spotting occurred in all spring barley varieties in all trials in 1999. The spotting occurred mostly on the upper leaf surfaces on leaf 1 and leaf 2, on awns and the upper leaf sheaths. Most of blackish-brown spots which occurred on the upper leaves, awns and upper leaf sheath of spring barley grown in Oak Park trials in 1999 were probably caused by the fungus *Ramularia collo-cygni*.

- Light either directly or indirectly may also be involved in producing the spot damage.

- Intensity form (shape) and colour of spots varied with variety and may also be influenced by environment and fungal spore load.

- All fungicide programmes significantly increased grain yield. Yield response to fungicide was due, for the most part, to a reduction in the level of necrotic spotting. The magnitude of yield response was dependant on the severity of necrotic spotting which was greatly influenced by variety.

- A two spray fungicide programme (T_1 at G.S. 30 and T_2 at G.S. 39) gives best control of spotting and conventional diseases with optimum yield response. The T_2 spray gives greatest control of spotting and yield enhancement.

- In the fungicide programmes trial strobilurins gave a greater yield response than non-strobilurin fungicides when used as the 2nd spray. No significant differences in terms of grain yield were detected between strobilurin fungicides and triazole fungicides when used as the first spray. The 2nd spray in barley was the more important in terms of the control of leaf necrosis and yield enhancement.

Plant Breeding and its Impact on Future Crop Production Systems

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INTRODUCTION

Depressed commodity prices, more stringent demands by end users and the gradual erosion and loss of subsidies, have placed farmers in an increasingly difficult position. Bear in mind the continual 'battle' with the 'elements' and it is only too easy to suggest that the future is bleak.

Perhaps now as we are into a new century is the time to take stock, look back where we have been and perhaps paint some picture as to where, with similar commitment to the past, we may go forward.

Growers are facing similar demands to those placed upon industrial producers, with downward pressure on prices and upward pressure on product quality. Industry needed to respond, now it is the turn of agriculture. This paper will review the current state of plant breeding, concentrating primarily on cereals, as well as the new technologies, which have been and are being developed to sustain crop production at a lower cost level with enhanced quality and hence improved marketing opportunities.

Crop Rotation

Options for rotations are severely limited by the number of 'break crops' available. As oilseed rape subsidies decline, growers have become increasingly interested in alternative crops to precede cereal growing. Unfortunately very few options exist, with many crops previously mooted as 'potentially useful' falling by the 'wayside' as realism replaces optimism. Linseed, linola and lupins have all had a place but growers have recognised that it will continue to be oilseed rape, peas, beans and sugar beet that will be the most significant break crops, certainly in the foreseeable future. Other crops will have a limited place but will be dependent on agreed outlets for production and hence will need support from buy-back contracts. Inevitably large breeders have concentrated resources on maize, soya and wheat with a neglect for 'break crops'.

Inevitably in a maritime climate this will push growers to more intensification of cereal production, particularly winter wheat. What can breeders do to sustain this option and particularly how can they mitigate the effects of the consequential increase in agronomic and disease pressure?

Will growers move further along the route of early drilling? What are the implications for variety selection?

Selection for Yield

There are no signs yet that breeders have exhausted the amount of natural variation for yield. Yields of wheat have increased at the rate of approximately 1% per annum for the last forty years. Progress in other crops is often slower as the resource applied is often smaller. It is inevitable that the advance in yields slow down as variation is used up. The development of short stature semi dwarf varieties gave a significant boost to wheat yields, as well as agronomic benefits, with few disadvantages. Later the use of the 1B/1R wheat/rye translocation appeared to give another boost to yields, though this time with detrimental consequences for grain quality. The effects of this translocation will be discussed when quality is considered.

With genetic yield improvements slowing over time, where can new variation for yield be derived? Certainly selection for grain yield *per se* will give forth to higher yielding varieties. Breeders are continually using new variation from around the World to enhance yield performance but this will still continue to be a slow process as breeders have to establish new variation in adapted germplasm before the value can be determined. This is a long process but can be assisted by the development of hybrids.

Hybrid wheat has been the goal of wheat breeders for nearly fifty years. Initial experiments using small quantities of hand produced hybrid seed suggested yield improvements of greater than 10% over standard varieties could be achieved. This has not materialised, with treated yields only marginally above the best conventional varieties. However, some companies are still pursuing hybrid wheat, Nickerson included, for other beneficial reasons. Cockpit winter wheat was a candidate for the UK Recommended List but failed to be recommended because of extreme susceptibility to yellow rust. However this variety did produce excellent yields of high quality grain suitable for bread making. When grown under second or continuous wheat situations this variety produced excellent results - superior to conventional inbred varieties. This advantage was not manifest in a first wheat situation. With an increasing emphasis being placed by growers on more continuous wheat, this clearly presents an opportunity to produce yields closer to first wheats but with significant benefits in terms of grain quality. Consistency of performance has often been cited as one reason for growing hybrid wheat. Our experiences suggest that these claims have some substance. This technology may well be insufficient to mitigate completely the effects of drilling as second or third wheats. However, new seed dressings for take-all control are currently being tested with promising results. The addition of this technology to the concept of hybrid wheat enhances the prospects for hybrid wheat development. The key to success will, however, be the cost of this technology and this is where both breeding and chemical companies (sometimes of course the same) need to recognise the financial problems in the market place.

Hybrid wheat will however lend itself to the identification of promising genetic combinations of yield. Once identified there are developing technologies such as genomics, which will increase the efficiency for identification and selection of desirable traits for incorporation into adapted germplasm.

Selection for Quality

Demands by end users and processors for improved grain quality will place severe constraints on the types of varieties grown. There is no genetic constraint to meeting the demands of the market - it will just take time and investment to adapt varieties to meet new demands.

There are some well-known end uses, which are unlikely to change in the foreseeable future. Bakers have spent large sums of capital in baking technology - they are unlikely to seek major change. The same is true for the biscuit industry, and it interesting to see the UK farmer this autumn 'retreat' into these 'safe havens' with increased shares for Malacca and Claire being realised.

Efficiency of selection for bread making has been increased by the identification of known high molecular weight protein glutenin subunits, known to be associated with bread making. This work was developed in the early 1980s and is now used as routine for screening new varieties. Work is also on-going to evaluate the role that gliadins may play in the bread making process.

In the Irish environment where high rainfall is often experienced at harvest time there are promising signs that pre-harvest sprouting can be usefully controlled in newer varieties such as Malacca. Using this material and known lines with good specific weight gives encouragement that improved varieties with good specific weight and high sprouting resistance can be obtained.

The feed industry is also coming to realise that there are opportunities to develop superior feeds. Breeders were unaware that one of the traits used as part of the strategy for improving yield (the 1B/1R wheat/rye translocation) gave rise to detrimental effects on grain quality. Sticky doughs as well as poor extensibility are known problems for the food sector. However, it is now known that this trait also has detrimental effects on poultry nutrition - particularly young broilers. Work is now progressing to develop superior higher yielding varieties without this potential problem. In addition work is also underway to evaluate varieties for pigs and ruminants.

The subject of genetic manipulation is the subject of much debate, but it is in the area of nutrition that much work is being concentrated. Starch modification, such that gelatinisation temperatures and starch profiles are radically altered, is an area targeted by many breeders. In addition, modifying the starch profile is likely to have significant effects on animal feed rations.

For the bread sector the incorporation of novel or multiple copies of high molecular weight glutenin subunits is underway. This could replace imports of so-called high quality wheats.

Agronomic Traits and Disease Resistance

With current prices, and no immediate return to higher levels of incomes, growers will naturally be cautious and seek to minimise their exposure to risk. Growing the right variety in terms of yield and quality will count for little if the growing costs and potential for loss through agronomic deficiencies undermine the marketability of the grain.

There are no deficiencies in terms of standing power. Semi dwarf varieties have paved the way for stiffer straw and there appears to be no shortfall in terms of genetic variation for this character.

Earliness of maturity is one area whereby breeders can move forward. We know what traits are involved and how they are inherited. Unfortunately breeders have still not resolved the problems associated with lower yields in selected lines which are early maturing. Growers may need to make a conscious decision to utilise slightly lower yielding varieties but with the prospect of securing better grain characters.

Disease resistance has been somewhat neglected by breeders, and certainly by the UK testing authorities, during the period of high grain prices. In terms of disease resistance there is no genetic shortfall. *Septoria spp.* are by far the most damaging disease for the Irish wheat grower. We now have available varieties which carry near immunity to this damaging disease. Currently in a variety with a yield potential some 5% lower than the highest yielding varieties, this resistance is being transferred to higher yielding lines. Very high levels of resistance to mildew (*Erysiphe graminis*) as well as for yellow rust (*Puccinia striiformis*) and brown rust (Puccinia recondita) are readily available. Likewise resistance for root diseases such as eyespot (*Pseuodercosporella herpotrichoides*) are available.

Biotechnology

Whilst much has been discussed publicly about the benefits or not of Genetically Modified Organisms (GMOs) scant attention has been paid to the exciting developments in biotechnology marker systems. These represent some of the most exciting prospects for variety selection in the new century. These systems pose no threat, perceived or otherwise, as they do not involve the modification or introgression of new genetic material. They are in essence merely the tools by which modern plant breeders identify the presence or otherwise of genetic traits.

One example of the power of this technology is the means by which the genetic make up of varieties can be identified. In the case of yellow rust, when the cultivar Brigadier succumbed to a new race (Yr17) in 1995 a number of other varieties succumbed at the same time - those varieties carrying this resistance. A number of varieties carrying this resistance along with another resistance gene (Yr6) could not be distinguished from other fully resistant varieties - other than by pedigree and conjecture. A new variant of this race, now combining virulence for Yr6 as well as for Yr17, evolved in 1998. This race will become prevalent across the UK in 2000 increasing the risks to growers of varieties now known to be susceptible. With genetic markers varieties could be identified by the association of markers with the genes involved and high-risk varieties identified.

Another example of how this technology can be utilised is the development and selection of 'novel' mildew resistance combinations. Similar systems can be developed for a series of resistance factors and varieties tested for these with one set of tests. Of high priority is the identification of markers to improve the selection efficiency for resistance to *Septoria spp*. Working in collaboration with a range of European breeders as well as established research institutes such as the John Innes Centre in Norwich, Nickerson has made elite germplasm available for this project. Resistance to *septoria spp.* is particularly complicated because it appears to be inherited through a series of genes rather than through single major genes.

The future for this technology is bright. Now mapping the whole genetic make up of wheat - GENOMICS - is becoming a reality. Knowing where genes are and how they are expressed should lead to significant advances in selection efficiency - with varieties selected for specific purposes - either end use or environmental.

However, Biotech companies are unlikely to recover the level of investment needed from this route alone. These companies require genetic modification - in the form of GMOs - to be successful. Their plans have been somewhat 'waylaid' by public perception problems and there is speculation that this alone may be sufficient for some to move away from the technology at least until the public perception problem is overcome.

But how useful is the technology for the future? There is of course no absolute answer - some of the examples cited before, such as starch modification, bode well. However, some of the claims put forward may have been exaggerated. There is of course deep interest in maintaining the momentum, especially among Biotech companies who have made very considerable financial investments in the technology. Failure is really not an option for some.

That being said there is no doubt that genetic modification can deliver benefits. The use of herbicide and pest resistance are tangible benefits, which have delivered exciting returns for North American growers. However, exhaustive testing will need to be carried out, in order to allay the concerns of the population at large. This does not appeal to many companies who seek more immediate return from their investments but some no doubt are prepared to stay with it in the long term.

Integration of Technologies

The future lies, just as it has in the past, with integrating new technologies. Over the last one hundred years we have seen how each aspect of crop growing is inter-related to another. Whether it be the development of monogerm sugar beet and the consequential development of precision drilling or the breeding of semi-dwarf wheat varieties and the consequential increased utilisation of nitrogen fertilisers one development leads to another. Cereal yields will increase, albeit at a lower pace initially than we have seen over the last 30 years. Varieties will not get shorter but will get stiffer. Genetic resistance to disease will assume greater importance. Grain will be tailored to specific uses and grown on a contract basis with end users.

In second and continuous wheats - genetic control of take-all (introduced via genetic modification) or the use of hybrid wheat are likely avenues for development and adoption. Specific seed dressings will be used in an integrated package as support for this regime.

CONCLUSIONS

In this part of Europe we are fortunate in that our climate lends itself to very high yield potential. However, the climate also lends itself to intense agronomic problems - disease, lodging and degradation of grain quality. Breeders have the means of overcoming these problems. Biotechnology is one route whereby we may see significant changes to agriculture in the new century. Modification of end use parameters - the evolution of industrial use of crops as well as faster development and responses to change. These along with evolving husbandry technologies give optimism that Irish arable production can be sustained at a lower cost basis than at present. However the pace of change will increase as outside pressures build. The future will thus be highly dependent on the transfer of this technology to growers.

Optimising Returns from Fungicides in Winter Wheat

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INTRODUCTION

The past season posed some difficulties for winter wheat growers. The wet autumn of 1998 resulted in late sowing of many crops. Equally the wet weather in May 1999 meant that there many problems in applying fungicide sprays on time, especially the flag leaf applications. This spell of wet weather resulted in quite high Septoria pressure during this period. Subsequently June and July had low rainfall amounts and the disease pressure eased considerably, leaving 1999 as a season of moderate disease pressure.

This paper covers three topics:

- The response to varying the fungicides used at the various key growth stages and the use of low rates.
- The performance of a number of fungicide products in 1999.
- The use of strobilurin fungicides in disease control programmes.

WINTER WHEAT FUNGICIDE PROGRAMMES

Trials were carried out in Co. Cork and Co. Kildare to evaluate the yield and disease responses from a number of fungicide programmes. The variety in Co. Cork was Falstaff while that in Co. Kildare was Brigadier. Most of these programmes were applied as three spray applications at growth stages 31, 39 and 59. Reduced rate fungicide programmes were applied as four spray applications at growth stages 31, 37, 45 and 59.

A programme consisting of Sportak at growth stage 31, Opus plus Amistar at growth stage 39 and Amistar at growth stage 59 was a standard programme against which all other programmes were compared. The other programmes had various products applied at these three growth stages. Full details of the programmes are shown in Table 1.

Table 1: Treatments - Fungicide Programmes

Treatment	Timing	Rate l/ha
Sportak Delta	31/32	1.25
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Sportak	31/32	0.9
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Allegro	31/32	1.0
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
S.Delta + Amistar	31/32	1.0 + 0.35
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Unix+Allegro+Opus	31/32	0.5+0.3+0.2
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Unix + Opus	31/32	0.5 + 0.6
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Sportak + Allegro	31/32	0.45 + 0.5
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Sportak	31/32	0.9
Allegro	37/39	0.8
Amistar	59	0.8
Sportak	31/32	0.9
Twist + Opus	37/39	1.2 + 0.3
Amistar	59	0.8
Flam Plus + Amistar	31/32	2.0 + 0.5
Opus + Amistar	37/39	0.3 + 0.8
Amistar	59	0.8
Sportak	31/32	0.9
Charisma + Amistar	37/39	0.75 + 0.5
Amistar	59	0.8
Sportak	31/32	0.9
Caramba + Amistar	37/39	0.5 + 0.8
Amistar	59	0.8
Sportak	31/32	0.9
Opus + Amistar	37/39	0.3 + 0.8
Caramba + Bravo	59	1.5 + 1.5
Allegro	31/32	0.8
Allegro	37/39	0.8
Amistar	59	0.8
Sportak	31/32	0.9
Allegro + Arma	37 + 45	0.33
Amistar + Arma	59	0.33
Sportak	31/32	0.9
Opus+Amistar+Arma	37/39	0.2 + 0.55
Amistar + Arma	59	0.55
Sportak	31/32	0.9
Flamenco + Amistar	37	0.5 + 0.8
Amistar	59	0.8
Unsprayed		

Growth stage 31 fungicides

Eight different fungicides were applied at growth stage 31. Yield and disease data for these treatments are shown in Table 2.

Table 2: Effect on yield and disease of various fungicides applied at growth stage 31

Fungicide	**Belgooly Co. Cork**	**C'carrigan Co. Kildare**	**% Eyespot Co. Cork**	**Belgooly Co. Cork**	**C'carrigan Co. Kildare**
	% Septoria 2nd Leaf			**t/ha @ 15% moisture**	
Sportak Delta Opus + Amistar Amistar	44	24	54	10.58	9.48
Sportak Opus + Amistar Amistar	56	50	47	10.10	9.24
Allegro Opus + Amistar Amistar	14	15	26	10.56	10.02
S.Delta + Amistar Opus + Amistar Amistar	31	17	30	10.87	9.70
Unix+Allegro+Opus Opus + Amistar Amistar	17	25	25	10.66	9.86
Unix + Opus Opus + Amistar Amistar	22	26	29	10.93	9.94
Sportak + Allegro Opus + Amistar Amistar	20	14	42	10.98	9.91
Flamenco Plus + Amistar Opus + Amistar Amistar	17	26	51	10.68	9.88
Unsprayed	100	100	75	6.46	5.77
L.S.D.	*11*	*14*	*16*	*0.43*	*0.55*

The yield responses were very high at both sites with all treatments giving substantially higher yields than the unsprayed. At Co. Cork all treatments yielded significantly higher than the standard growth stage 31 treatment of Sportak. In Co.Kildare there was a similar outcome with the exception of two treatments (Sportak Delta and Sportak Delta plus Amistar) which did not give a significantly different yield than the standard treatment. At this site there was an outbreak of yellow rust and these two treatments did not fully contain the disease which obviously resulted in the lower yields from these treatments.

The majority of the treatments at both sites had significantly lower levels of Septoria on the second leaf than the standard treatment, the exception being Sportak Delta at Co. Cork. As these septoria measurements were carried out in early July they demonstrate the potential season long effects from a fungicide at growth stage 31.

Eyespot levels were measured at the Co. Cork site only. All treatments had significantly lower eyespot than the untreated, however, there were significant differences between the treatments also.

Growth stage 39 fungicides

The growth stage 39 treatments were designed to examine the effect on yield and disease levels by varying the products or mixtures of products used at this spray timing. The standard growth stage 39 treatment was a mixture of Opus and Amistar. Results for these treatments are shown in Table 3.

Table 3: Effect on Yield and Disease of Various Fungicides applied at growth stage 37/39

Fungicide	**Belgooly Co. Cork**	**C'carrigan Co. Kildare**	**Belgooly Co. Cork**	**C'carrigan Co. Kildare**
	% Septoria 2nd Leaf		**t/ha @ 15% moisture**	
Sportak Opus + Amistar Amistar	56	50	10.10	9.24
Sportak Allegro Amistar	45	44	10.35	8.95
Sportak Twist + Opus Amistar	52	39	10.33	9.20
Sportak Charisma + Amistar Amistar	78	64	9.50	8.96
Sportak Caramba + Amistar Amistar	86	72	9.57	8.97
Sportak Flamenco + Amistar Amistar	55	68	10.31	9.02
Unsprayed	100	100	6.46	5.77
L.S.D.	*11*	*14*	*0.43*	*0.55*

There was no significant yield difference between any of the growth stage 39 treatments at the Co. Kildare site. In Co. Cork two treatments (Caramba plus Amistar and Charisma plus Amistar) were lower yielding than the other treatments.

There were differences between these treatments when disease levels are examined. In Co. Kildare three of the treatments and in Co. Cork had significantly higher disease levels than the standard treatment.

Growth stage 59 fungicides

Only two treatments were compared at this growth stage – Amistar and a mixture of Caramba and Bravo. Results are shown in Table 4.

Table 4: Effect on Yield of Various Fungicides applied at growth stage 59

Fungicide	**Belgooly Co. Cork**	**C'carrigan Co. Kildare**	**Belgooly Co. Cork**	**C'carrigan Co. Kildare**
	% Septoria 2nd Leaf		**t/ha @ 15% moisture**	
Sportak Opus + Amistar Amistar	56	50	10.10	9.24
Sportak Opus + Amistar Caramba + Bravo	86	72	9.57	8.97
Unsprayed	100	100	6.46	5.77

The standard Amistar at G.S. 59 gave significantly lower disease levels at both sites and a significantly higher yield at Belgooly.

Reduced rates of fungicide

Table 5 shows the result of using reduced rates of fungicide. One reduced rated treatment was two-thirds rate of the standard programme while the other reduced rate treatment consisted of two thirds Allegro followed by one third Amistar. The reduced rate treatments were used with the additive Arma. These treatments were applied over three spray applications at growth stages 37, 45 and 59.

Table 5: Yield and disease levels of reduced rate programs compared with standard program

No.	Fungicide	Belgooly Co. Cork	C'carrigan Co. Kildare	Belgooly Co. Cork	C'carrigan Co. Kildare
		% Septoria 2nd Leaf		t/ha @ 15% moisture	
2	Sportak Opus + Amistar Amistar	56	50	10.10	9.24
15	Sportak Alllegro + Arma Amistar + Arma	55	26	9.68	9.36
16	Sportak Opus + Amistar + Arma Amistar + Arma	53	62	9.99	9.03
18	Unsprayed	100	100	6.46	5.77

There was no significant yield difference between the reduced rate treatments and the standard treatment at either site. Neither was there any significant difference between the disease levels with the exception of Allegro at Co. Kildare, which gave low disease levels. Because of wet weather in May the planned growth stage 37 time of application of treatment 15 at Co. Cork was delayed until growth stage 39 which placed this treatment at a disadvantage.

FUNGICIDE COMPARISON TRIALS

A two-spray fungicide programme trial was carried out on Brigadier winter wheat at Knockbeg in 1999. Seven fungicide treatments were compared with an unsprayed control in a six fold replicated trial. The fungicides were applied at growth stages 39 and 59. There were moderate levels of Septoria in the trial. Yellow rust appeared in this crop in late April 1999 and had defoliated the unsprayed plots by early June, which accounts for the extremely low yields in the untreated. The yield difference between the untreated and the treated plots is mainly due to yellow rust while any differences between treatments is due to Septoria and yellow rust control. Yield and disease data for this trial are shown in Table 6.

Table 6: Two-spray fungicide program experiment on Brigadier winter wheat at Knockbeg 1999

Fungicide	Rate l/ha	1000 grain wt. (g)	Kg/hl	% Necrosis 2nd Leaf	Yield t/ha (15% MC)
Amistar + Opus	0.8 + 0.5	47.5	71.2	63	9.67
Amistar	1.0				
Amistar + Opus	1.0 + 1.0	49.3	70.9	59	9.95
Amistar	1.0				
Allegro	1.0	47.7	71.1	68	9.47
Amistar	1.0				
Sphere	1.0	46.0	70.3	75	9.23
Sphere	1.0				
Twist + Opus	1.5 + 1.0	49.0	71.0	62	9.65
Twist + Opus	1.5 + 1.0				
Charisma + Allegro	1.5 + 0.6	46.6	70.6	68	9.25
Charisma + Amistar	0.75 + 0.8				
Caramba + Amistar	1.0 + 0.8	45.3	69.8	82	9.07
Caramba + Amistar	1.0 + 0.8				
Untreated		31.4	60.3	100	4.44
L.S.D.		*2.6*	*1.5*	*11.4*	*0.4*

Yield responses to treatment were high in this trial ranging from 4.6 to 5.5 t/ha over the untreated control. A major part of this response arose from yellow rust control. The rust was in general well controlled by the various spray treatments. The impact of the yellow rust ensured that the treatment effect on yield 1000 grain weight and kg/hl was significant. Actual Septoria levels were moderate; the leaf necrosis was due to a combination of control of both diseases.

THE USE OF STROBILURIN CONTAINING FUNGICIDES

Strobilurin fungicides are now well established in cereal disease control programmes. There are two currently on the market and in the coming season there will be another one released with more in the pipeline for release over the next few years. They do give a yield increase over and above what can be expected from straight disease control. Table 7 shows the results from a trial carried out at Oak Park in 1999 comparing triazoles and strobilurins alone and in mixtures.

Table 7: A comparison of strobilurin and triazole fungicide programmes on winter wheat cv. Falstaff at Oak Park in 1999

Programme	Yield t/ha @ 15%	%Green area Flag Leaf	% Septoria Leaf 2	Kg/hl	1000 grain wt. (g)	Screening %
T_1 Unix 0.67*l* + Allegro 0.5*l* T_2 Allegro 1.0*l* T_3 Amistar 0.8*l*	12.5	13.9	2.3	78.64	54.55	1.34
T_1 Unix 0.67*l* + Opus 0.5*l* T_2 Opus1.0*l* T_3 Opus1.0*l*	12.0	9.3	2.2	78.07	51.45	1.57
T_1 Unix 0.67*l* + Opus 0.5*l* T_2 Opus 1.0*l* T_3 Amistar 0.8*l*	12.3	12.7	2.3	78.57	53.18	1.46
T_1 Unix 0.67*l* + Opus 0.5*l* T_2 Allegro 1.0*l* T_3 Opus 1.0*l*	12.2	12.8	2.1	78.41	52.60	1.52
L.S.D.	*0.19*	*n.s.*	*n.s.*	*0.23*	*1.05*	*0.16*

Disease levels were low in Oak Park in 1999. There was no difference in disease levels between the programmes in this trial. There were significant differences in yield however with the programme containing two strobilurin applications giving the highest yield. This latter programme and the programmes containing one strobilurin application were significantly higher yielding than the non strobilurin programme. The difference in green leaf area between the programmes is a factor in this yield benefit.

Strobilurin fungicides give a significant yield benefit and it is important that they are used in a manner that ensures their long-term advantage. Mildew resistance to strobilurins has already appeared and there are recommendations for mixing mildewicides with them to overcome this problem.

The Fungicide Resistance Action Committee (FRAC) has issued guidelines on the use of strobilurins which includes tank mix partners and also recommends that no crop should receive more than two applications of a strobilurin in a season.

CONCLUSIONS

- There are good alternative treatments to strobilurins at the growth stage 31 spray timing.
- Opus is the preferred triazole to mix with a strobilurin at the growth stage 39 stray timing.
- Disease control programmes will consist of mixtures of strobilurins and non-strobilurins.
- There is a yield response to strobilurins over what can be explained by disease control alone.
- Because of the risk of disease resistance only two strobilurins should be applied to a crop in any season.
- New strobilurin fungicides will lead to further advances in disease control.

Is there a Role for Liquid Fertilisers on Tillage Farms?

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INTRODUCTION

In the early 90's, a new and novel means (liquid Flex system) of crop fertilisation was launched on the Irish market which was capable of supplying the crop's total nitrogen, phosphorus, potassium and trace element requirement in liquid form, formulated to meet specific crop requirements. This system included a unique formulation and was untested under Irish conditions.

Liquid fertilisers offer some potential benefits over solid fertilisers. These benefits include, easier to spread evenly, easier to apply intended amount, easier to transport and handle, less on-farm labour, more intensive use of sprayer, increased application window and tailored formulations.

The chemistry of the liquid Flex system consists of an acid-based material. Stable compounds i.e. urea sulphate, urea phosphate and urea-metal complexes are formed by the reaction of urea with sulphuric acid, phosphoric acid and metal salts, respectively. Interest in these materials has been generated because they possess a number of physical and chemical characteristics, which, in theory, should be beneficial. However, the ability of the Flex system to effectively supply nutrients to the plant has not been researched.

There were four main areas identified where new information was needed.

(1) The effectiveness of urea-phosphate in supplying phosphorus to the plant, in a field or controlled environment situation. All the phosphorus in the liquid system is in the form of a urea-phosphate complex.

(2) The efficiency of the Flex main commercial source of nitrogen, N24 (urea with the addition of a standard level of phosphoric acid, sulphuric acid and metal-salts), in comparison with conventional nitrogen types i.e. CAN and urea.

(3) The performance of complete acid-based liquid fertiliser programmes compared with conventional granular systems. This is important in situations where soil phosphorus reserves are low, where the early or autumn application of phosphorus can be critical in obtaining maximum response. In these situations, due to the bond between nitrogen and phosphorus in the Flex system, the application of 1 kg/ha of P must be accompanied by at least 1 kg/ha of N. This complication will have implications for nitrogen use efficiency.

(4) The effect of the addition of inorganic salts to urea, applied late in the season, as a foliar spray to boost protein content of wheat. This nitrogen chemistry is the basis for an additional product of the Flex system i.e. liquid Flex urea - N18.

Consequently, a field and greenhouse experimental programme was carried out over the three seasons 1996-1998 to evaluate and compare the response to acid-base/urea-metal complexes with conventional fertilisers. The trial programme evaluated the Flex system, both as individual components and as a complete fertiliser.

A Comparison of Liquid Urea Phosphate with Superphosphate

Urea phosphate was compared with superphosphate as a P source in field experiments over the three growing seasons 1996-1998. Sites were selected on the basis of a low soil P reserve, where both fertilisers were applied at a number of rates and different timings.

Two winter wheat field trials were carried out in 1996 at Summerhill, Co. Meath and Mooncoin, Co. Kilkenny with soil P levels of 1.6 and 2.0 ppm respectively. In both sites the cultivar grown was Brigadier. Both trials included two products, a urea-urea phosphate mixture (15% N, 8.5% P), and superphosphate (16% P) applied at six P rates: 10, 20, 30, 40, 50, and 60 kg/ha. Phosphorus treatments were applied to the soil surface in late March at both sites.

Two similar field trials were carried out in 1997 and 1998 at Summerhill, Co. Meath with soil P levels of 2.5 and 1.3 ppm respectively, and Piltown, Co. Kilkenny in 1997, with a soil P level of 3.4 ppm, with the cultivar Brigadier. Both trials included two P products, urea phosphate (3% N, 3% P) and superphosphate (16% P) applied at three P rates: 20, 40 and 60 kg/ha. Phosphorus treatments were applied to the soil surface at three timings, full in autumn, full in spring and half autumn/half spring.

In the field comparisons, no differences were detected between P source in grain yield (Table 1) or grain quality parameters in any of the trials in 1996 and 1997. Because of the significant interactions between the factors affecting yield at Summerhill in 1998, it is not possible to draw any conclusions on the relative efficiencies of urea phosphate in comparison to conventional granular superphosphate in that trial. However, there only existed a difference of 0.03 t/ha between the mean of all urea phosphate and the mean of all superphosphate treatments. These results are reinforced by an analysis of grain P content and total P uptake in grain.

Table 1: Grain yields (t/ha @ 15% moisture content) as affected by phosphorus source

	Mooncoin	**Piltown**		**Summerhill**	
	1996	**1997**	**1996**	**1997**	**1998**
Phosphorus source					
Superphosphate	10.622	8.840	11.343	11.030	8.410
Urea phosphate	10.905	8.940	11.452	10.970	8.380
Level of sig.	*n.s.*	*n.s.*	*n.s.*	*n.s.*	-

Because field experiments have only a limited ability to detect a difference in plant yield between P fertilisers, further experiments were carried out under controlled conditions, further evaluating urea phosphate in comparison to superphosphate.

Three soils; a heavy clay soil from Co. Meath, a heavy clay soil from North Co. Dublin and a somewhat lighter soil from Co. Kilkenny were potted in 3.5 inch pots and sown with spring barley (c.v. Optic). Morgan's P values were 3.0, 4.0 and 2.0 ppm for the soils from Meath, Dublin and Kilkenny, respectively. Superphosphate (16% P) and urea phosphate (3% P/3% N) were applied at the rate of 25, 50 and 75 mg P per pot. Pots were watered weekly with a P-free nutrient solution to optimise growing conditions. Three harvests were taken from each treatment by cutting the plants at soil level: 42, 62 and 86 days after sowing.

At harvests 1 and 2, no differences were observed between P sources in total dry matter production (Table 2). These results indicate that urea phosphate was equally efficient as superphosphate in supplying P to the plant and was not influenced by soil type or P rate. The interactive effect between P type and rate in total dry matter production at harvest 3 cannot be explained. However, when total dry matter production at harvest 3 was combined with the whole plant P content, no significant difference existed between P types in total P uptake. This data reinforces the hypothesis that urea phosphate and superphosphate are equivalent in P supply and crop yield.

Table 2: The effect of P source, at three P rates, over three soil types, on total dry matter production measured on three harvest dates and total P uptake measured at harvest 3

	Harvest 1 DM (g)	**Harvest 2 DM (g)**	**Harvest 3 DM (g)**	**Harvest 3 P uptake (mg)**
Phosphorus type				
Urea phosphate	1.03	3.92	8.68	11.19
Superphosphate	0.99	3.99	8.98	12.33
Level of sig.	*n.s.*	*n.s.*	-	*n.s.*

Response to P application in the field experiments varied according to site. Many factors contribute to this response variation including soil P status, soil type and seasonal growing conditions. In general, response to fresh applications of P was low, even though the soils were selected on the basis of a likely yield response. However, the data from the field and greenhouse experiments indicated a reduced response to applied P fertiliser as soil P level increased above index 1, i.e. 3.0 ppm. This reinforces the important role of soil P analysis in determining optimum P application rates.

The timing of P application in the field experiments accounted for little variation in P uptake and grain yield. Winter wheat crops responded to spring applications of P. However, in soils where P reserves were extremely deficient i.e. Summerhill 1998 (1.3 ppm), a greater response was obtained from an earlier application compared to P applied in spring.

A Comparison of Liquid Flex N24 with Calcium Ammonium Nitrate and Urea as Main Nitrogen Sources

Because urea is cheaper than ammonium nitrate, there is an interest in its use for cereals. In general, urea is as effective as CAN early in the growing season, less so in summer. The main reason for loss of efficiency of urea is volatilisation of ammonia. In contrast, leaching and denitrification are the principal loss mechanisms with ammonium nitrate. The addition of acids and inorganic salts appear to have considerable potential for improving the efficiency of urea. Nitrogen would be released slowly, and leaching and volatilisation reduced.

The liquid Flex main nitrogen source, N24 (urea with the addition of sulphuric acid, phosphoric acid and some inorganic salts) was compared with CAN and urea at two sites in 1997 and one site in 1998 on the cultivar Brigadier. The trials were carried out at Oak Park, Co. Carlow and Ardclough, Co. Kildare in 1997 and at Ardclough in 1998. Liquid N24 (24% N w/w) was compared with CAN and granular urea in 1997 and CAN, granular urea and liquid urea in 1998 at 100, 150, 200 and 250 kg N/ha in split applications at conventional timings. The N24 (due to its slower N release nature) was also applied at timings two and four weeks earlier than conventional.

At Oak Park in 1997, liquid N24 gave a lower N uptake and grain yield than granular urea, and both were inferior to CAN (Figure 1). Similar results were observed at Ardclough. Since the weather was dry and warm at the time of application, ammonia volatilisation may account for these results. In addition, the amount of acid inhibitor may not have been sufficient to eliminate this loss. The difference in performance between granular urea and N24 is explained by the increased surface area of liquid that is exposed to the soil particles and therefore the urease enzyme which gives rise to urea hydrolysis. The slower breakdown of the urea granule leads to a lower rate of urea hydrolysis, which in turn can delay the time at which maximum rates of ammonia loss occurs.

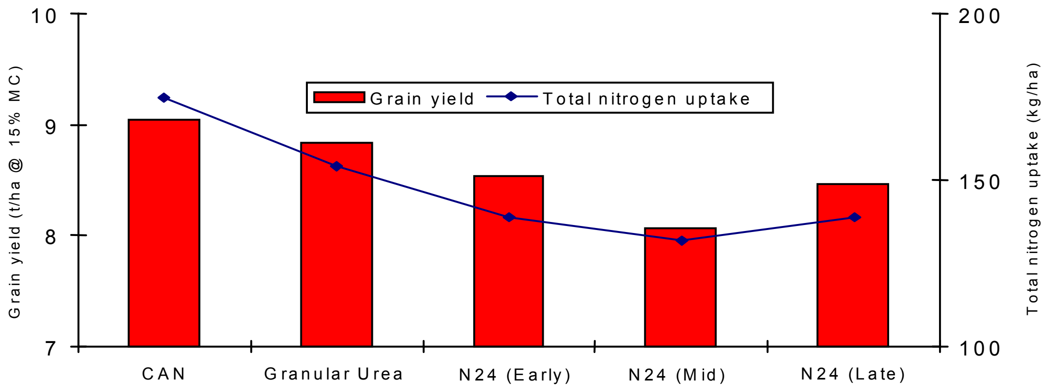

Fig. 1: Grain yield and total nitrogen uptake as affected by nitrogen system (average of four nitrogen rates), Oak Park, 1997

The liquid N24 gave a more positive response in 1998 (Figure 2). This is almost certainly due to the high rainfall recorded during the spring of that year, which may have led to leaching losses from CAN and urea. N24, being a slow nitrogen release source, may have suffered less in this respect. Significantly higher soil nitrate levels were recorded where CAN was used in comparison to N24 applied late, when measured in mid-May.

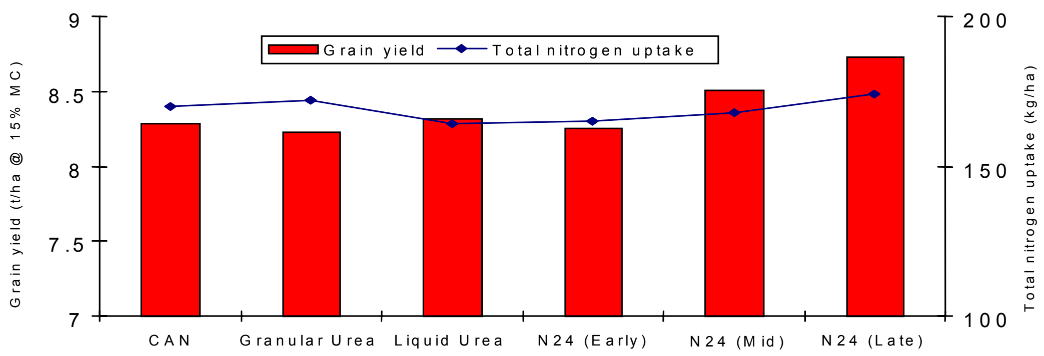

Fig. 2: Grain yield and total nitrogen uptake as affected by nitrogen system (average of four nitrogen rates) Ardclough, 1998

The difference in performance between years with different N types i.e. N24, urea and CAN, reflects the susceptibility of the N sources to different N loss mechanisms, depending on environmental conditions. The loss mechanism of most significance for urea and N24 is volatilisation. N24 may not be inhibited enough to substantially reduce NH_3 loss in situations where loss is likely to occur. The amount of NH_3 loss associated with N24 greatly depends on the time of application and the amount of rainfall after fertiliser application. The slow release of N from N24 may reduce the potential loss from leaching or denitrification during periods of heavy rainfall.

A Comparison of Complete Acid-Based Liquid Fertilisation Programmes with Conventional Granular Systems

In the two previous sections urea phosphate and acid-based nitrogen have been separately compared with conventional phosphorus and nitrogen sources. This section compares complete liquid-based fertiliser systems with their conventional equivalents.

Comparison of complete fertiliser systems for winter wheat is complicated by the bond between nitrogen and phosphorus in the liquid system (Pure urea phosphate has approximately the same level of N to P, i.e. 17.7% N and 19.6% P). This dictates that the application of 1 kg of phosphorus must be accompanied by at least 1 kg of nitrogen.

Three experiments were carried out at Summerhill, Co. Meath in 1997 and 1998 and at Piltown, Co. Kilkenny in 1997, on the cultivar Brigadier, to compare complete liquid and granular fertilisation systems. The sites were selected on the basis of a low soil phosphorus reserve where yields were most likely to be influenced by the rate and timing of nitrogen and phosphorus application. Since phosphorus cannot be applied on its own in the liquid system, i.e. urea phosphate, early application of phosphorus would obviously affect nitrogen use efficiency. A compromise was therefore necessary at the first application of the liquid treatments. Phosphorus application was kept below the desired level, to reduce the application of undesired levels of nitrogen. Results from soil analysis for each site are presented in Table 3.

Table 3: Soil analysis reports for each site

	Summerhill 1997		**Piltown 1997**		**Summerhill 1998**	
pH	**6.3**		**5.8**		**6.0**	
	mg/l	**Index**	**mg/l**	**Index**	**mg/l**	**Index**
Phosphorus (P)	2.5	V. Low	3.4	Low	1.3	V. Low
Potassium (K)	51	Low	135	Medium	38	V. Low
Magnesium (Mg)	74.3	Medium	237	High	39.8	Low
Copper (Cu)	12.1	High	4.7	High	7.7	High
Zinc (Zn)	5.5	High	2.9	Medium	5.0	High
Manganese (Mn)	325	High	430	High	439	High

Three fertiliser programmes were included: the recommended rate based on soil analysis, and 30% above and below this level. The N, P and K requirements for each trial site are presented in Table 4.

Table 4: N, P and K requirements for trial treatments (kg/ha)

	Recommended rate	30% lower	30% higher
Summerhill 1997			
Nitrogen	185	130	240
Phosphorus	45	32	59
Potassium	75	53	98
Summerhill 1998			
Nitrogen	185	130	240
Phosphorus	45	32	59
Potassium	95	67	124
Piltown 1997			
Nitrogen	185	130	240
Phosphorus	35	25	46
Potassium	60	42	78

Fertiliser type, rate and timing of application for individual treatments, in all three trials, are presented in Tables 5-7. All granular N, P and K fertiliser was applied as CAN (27.5% N), superphosphate (16% P) and muriate of potash (50% K).

Table 5: Systems trial Summerhill 1997 treatments

	LIQUID	
Recommended rate	**30% lower rate**	**30% higher rate**
500 kg/ha 6-4-8	350 kg/ha 6-4-8	650 kg/ha 6-4-8
12/12/96	12/12/96	12/12/96
500 kg/ha 15-4-5	350 kg/ha 15-4-5	650 kg/ha 15-4-5
04/03/97	04/03/97	04/03/97
450 kg/ha 19-2-3	315 kg/ha 19-2-3	585 kg/ha 19-2-3
26/03/97	26/03/97	26/03/97
	SOLID	
Recommended rate	**30% lower rate**	**30% higher rate**
45 kg/ha P	32 kg/ha P	59 kg/ha P
75 kg/ha K - 12/12/96	53 kg/ha K - 12/12/96	98 kg/ha K - 12/12/96
75 kg/ha N - 13/03/97	75 kg/ha N - 13/03/97	75 kg/ha N - 13/03/97
110 kg/ha N - 10/04/97	55 kg/ha N - 10/04/97	165 kg/ha N - 10/04/97

Table 6: Systems trial Piltown 1997 treatments

LIQUID		
Recommended rate	**30% lower rate**	**30% higher rate**
450 kg/ha 7-4-7	315 kg/ha 7-4-7	585 kg/ha 7-4-7
05/12/96	05/12/96	05/12/96
450 kg/ha 15-2-6	315 kg/ha 15-2-6	585 kg/ha 15-2-6
27/02/97	27/02/97	27/02/97
450 kg/ha 20-1-0	315 kg/ha 20-1-0	585 kg/ha 20-1-0
25/03/97	25/03/97	25/03/97
SOLID		
Recommended rate	**30% lower rate**	**30% higher rate**
30 kg/ha P	25 kg/ha P	46 kg/ha P
60 kg/ha K - 05/12/96	42 kg/ha K - 05/12/96	78 kg/ha K - 05/12/96
75 kg/ha N - 14/03/97	75 kg/ha N - 14/03/97	75 kg/ha N - 14/03/97
110 kg/ha N - 11/04/97	55 kg/ha N - 11/04/97	165 kg/ha N - 11/04/97

Table 7: Systems trial Summerhill 1998 treatments

LIQUID		
Recommended rate	**30% lower rate**	**30% higher rate**
400 kg/ha 3-3-8	280 kg/ha 3-3-8	520 kg/ha 3-3-8
14/01/98	14/01/98	14/01/98
700 kg/ha 8-3-7	490 kg/ha 8-3-7	910 kg/ha 8-3-7
31/03/98	31/03/98	31/03/98
650 kg/ha 20-1-1	455 kg/ha 20-1-1	845 kg/ha 20-1-1
17/04/98	17/04/98	17/04/98
SOLID		
Recommended rate	**30% lower rate**	**30% higher rate**
45 kg/ha P	32 kg/ha P	59 kg/ha P
95 kg/ha K - 14/01/98	67 kg/ha K - 14/01/98	124 kg/ha K - 14/01/98
65 kg/ha N - 20/03/98	65 kg/ha N - 20/03/98	65 kg/ha N - 20/03/98
120 kg/ha N - 25/04/98	65 kg/ha N - 25/04/98	176 kg/ha N - 25/04/98

In all but one of these trials, granular fertiliser gave higher grain yields than liquid (Figures 3-5). The only exception was at Summerhill in 1997, where liquid gave a significantly higher grain yield than solid at the 30% higher than recommended fertiliser rate (Figure 3). The high level of lodging explains this result. The yield difference between solid and liquid was reflected in a significant difference in total crop N uptake with granular being higher than liquid in all cases.

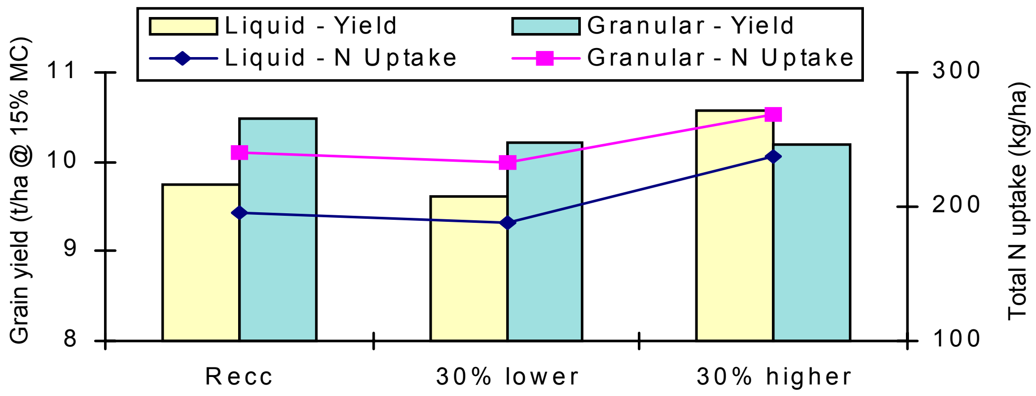

Fig. 3: The effect of fertiliser programme on wheat grain yield and N uptake (Summerhill, 1997)

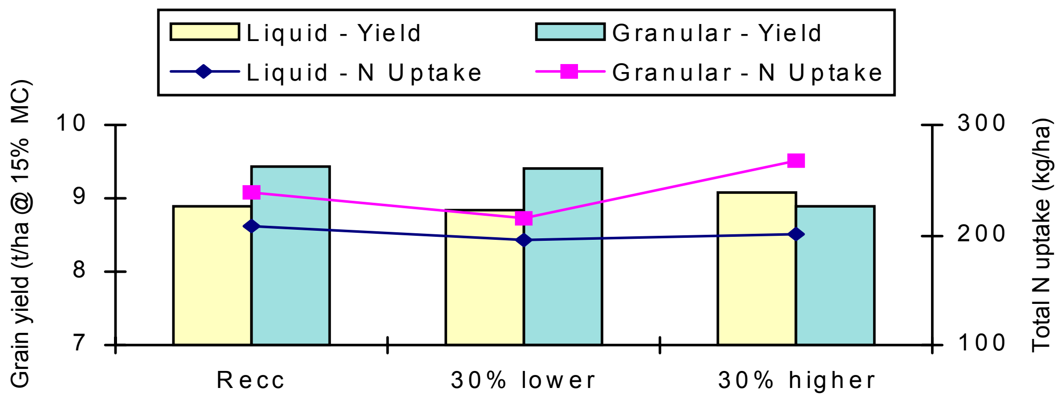

Fig. 4: The effect of fertiliser programme on wheat grain yield and N uptake (Piltown, 1997)

There was a small variation in the total amount of nutrient applied between solid and liquid. However, this would not have been considered to contribute, to any great extent, to the difference in performance between the two systems. Therefore, the difference that existed in the performance between solid and liquid is either due to (1) timing of the nutrient application or (2) the different chemistry associated with both.

There was a big distinction in the timing of the fertiliser application between solid and liquid. Liquid fertiliser application resulted in delayed P and K application and the application of N during undesirable times i.e. autumn, winter and early spring.

Given that soil K levels were reasonable at Summerhill (51 ppm) in 1997 and quite good (135 ppm) at Piltown, grain yield would not be expected to be penalised when some of the K was applied in the autumn period. Separate trials on the same sites in 1997, as discussed in the phosphorus section, showed no yield response to applied P at Piltown. A significant yield response was observed up to 20 kg/ha of P in Summerhill, but this was not significantly affected by timing or by P type. As a result, the timing of P and K application can be ruled out as the reason for a difference in performance between solid and liquid fertiliser, regardless of their different chemistry. It is likely that the timing of N application had the most significant effect.

There is strong evidence to suggest that the N applied in December with the liquid treatments was lost over the winter and early spring by leaching. Some loss from the early spring applications may further explain the differences in grain yield and total N uptake between the two systems in 1997.

The difference in chemistry between N types may have also contributed to the difference in performance between solid and liquid. As discussed in the previous section, liquid Flex nitrogen varies in performance from year-to-year when compared with CAN. The difference in efficiency between solid and liquid cannot be solely attributed to either the different nitrogen chemistry or timing of application. However, in all probability, the chemical difference in N between solid and liquid played a much smaller part than the time of application in the overall performance between both systems.

A somewhat different scenario was encountered in 1998 where P and K levels in soil were extremely deficient (Figure 5). Grain yield fell, but not significantly, at the lower fertiliser level; there was little increase at the higher level. The liquid system gave lower yields and N uptakes; this may be due to the later application of P and K within the liquid system, which restricted yield potential and reduced the response to the subsequent application of nitrogen. Early P application gave a more positive yield response than later applications in a separate trial on the same site. The possible loss of nitrogen over the winter period with the liquid systems may further explain the difference in performance.

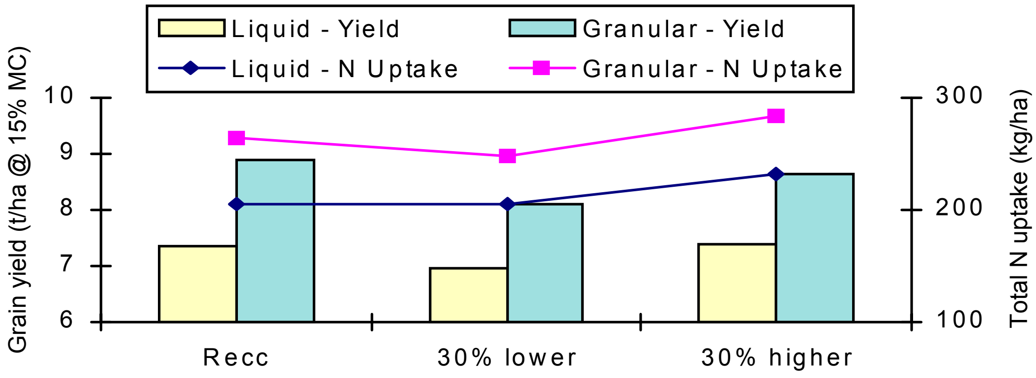

Fig. 5: The effect of fertiliser programme on wheat grain yield and N uptake Summerhill, 1998)

The current trials demonstrate the difficulties of using the liquid system under study in situations of low soil P and K supply. In such situations, the early timing of P and K can be critical to maximise grain yields. The early application of P as urea phosphate has very serious implications for N efficiency. The application of N in the autumn and winter period is very much at risk of being lost from nitrate leaching and has little, if any positive effect on final grain yield.

A Comparison of Liquid Urea with Liquid Flex Urea as Late Nitrogen Sources

The efficiency of foliar applied nitrogen, as urea can be very variable and often low. Reports suggest that the most likely cause of inefficiency is volatilisation of ammonia.

Reports from a number of studies demonstrate the ability of inorganic salts such as $CaCl_2$, $Ca(NO_3)_2$, KCL, KNO_3 and $MgSO_4$ to lower NH_3 volatilisation from urea when applied to soil. Little or no information is reported on the effect of the addition of these inorganic salts to urea when applied to the foliage of winter wheat as a foliar spray. If the same holds for foliar application as with soil application, then the altering of urea with the addition of this type of chemicals has therefore, the potential for increased efficiency of foliar applied urea.

A series of field trials were carried out over the 1996-1998 growing seasons to study the effect of late nitrogen on the yield and protein content of winter wheat and, in particular, to compare liquid urea with liquid Flex urea i.e. N18, (addition of inorganic salts e.g.$CaCl_2$) as a late nitrogen source.

In 1996, a trial was carried out at Oak Park, Carlow to compare late N sources on the cultivar Brigadier. Liquid urea was made up as a 10% N solution w/v while liquid Flex urea was somewhat more concentrated at 18% N solution w/w. These were applied at four late N rates:

20, 30, 40 and 50 kg/ha. All treatments received a basal dressing of 160 kg/ha of N as CAN. All late N treatments were applied on 19/06/96 at the milky ripe stage. Data are presented in Table 8 for grain yield, protein content and total grain N.

Table 8: Grain yield, protein content and total grain N as affected by late N source (Oak Park, 1996)

	Grain yield (t/ha @ 15% MC)	**Grain protein content (% @ 15% MC)**	**Total grain N (kg/ha)**
Liquid urea	10.54	8.59	158
Liquid Flex urea	10.63	8.48	158
Level of sig.	*n.s.*	*n.s.*	*n.s.*

During the 1997 and 1998 growing seasons, field trials were carried out at Oak Park, Carlow and Ardclough, Co. Kildare on the cultivar Brigadier. Liquid urea was made up as a 10% N solution w/v while liquid Flex urea was diluted down to 10% N solution w/v. These N sources were applied at five rates: 10, 20, 30, 40 and 50 kg/ha. All treatments received a basal dressing of 160 kg/ha of N as CAN. All late N treatments were applied at the milky ripe stage on 30/06/97 and 27/06/97 and 30/06/98 and 25/06/98 at Oak Park and Ardclough, respectively. Data are presented for grain yield (t/ha @ 15% moisture content), protein content (% @ 15% moisture content) and total grain N (kg/ha) in Tables 9 and 10, for the trials in 1997 and 1998, respectively. The effect of late N source and rate on flag leaf scorch at Ardclough in 1997 and Oak Park in 1998 is presented in Figures 6a and 6b, respectively.

Table 9: Grain yield, protein content and total grain N as affected by late N source (Ardclough and Oak Park, 1997)

	Ardclough			**Oak Park**		
	Grain yield	**Protein content**	**Total grain N**	**Grain yield**	**Protein content**	**Total grain N**
Liq urea	10.84	8.70	166	10.39	9.33	170
Liq Flex urea	10.72	8.87	167	10.14	9.40	167
Level of sig.	*0.05*	*n.s.*	*n.s.*	*n.s.*	*n.s.*	*n.s.*

Table 10: Grain yield, protein content and total grain N as affected by late N source (Ardclough and Oak Park, 1998)

	Ardclough			**Oak Park**		
	Grain yield	**Protein content**	**Total grain N**	**Grain yield**	**Protein content**	**Total grain N**
Liq urea	9.22	8.33	135	9.78	9.77	167
Liq Flex urea	9.44	8.43	140	9.84	9.53	164
Level of sig.	*n.s.*	*n.s.*	*0.01*	*n.s.*	*0.05*	*n.s.*

NOTE: Late N treatments were washed from leaves due to a heavy shower immediately after application at Ardclough in 1998. As a result, uptake of late N occurred mostly via the root system.

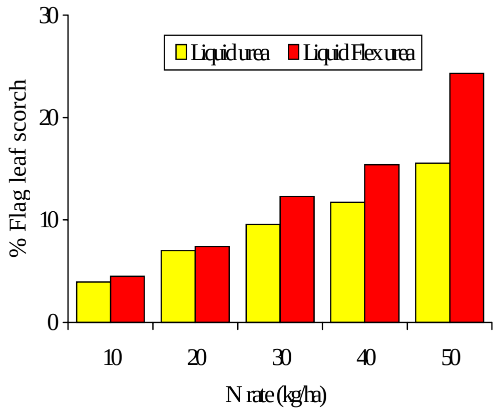

Fig. 6a The effect of late N source and rate on flag leaf scorch (Ardclough, 1997)

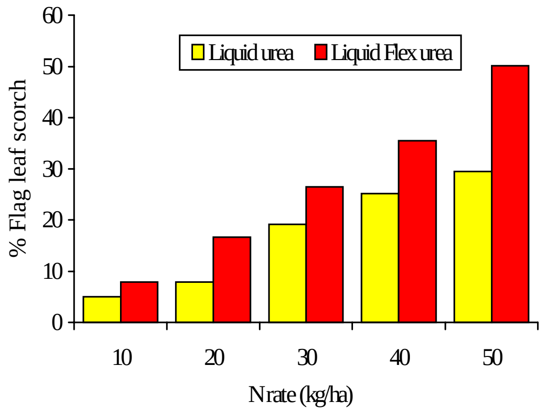

Fig. 6b The effect of late N source and rate on flag leaf scorch (Oak Park, 1998)

Throughout the current set of trials, liquid Flex urea (N18) was, in general as efficient as liquid urea as a late N source in terms of grain yield, protein content and N recovery in grain. However, liquid Flex urea consistently gave higher scorch levels than liquid urea.

Scorch levels varied from year to year. Higher rates of late N increased flag leaf scorch. A scorch level of 20% would seem to be the threshold value, which if exceeded, has a negative effect on grain yield.

The hectolitre and the mean grain weight tended to decrease and screenings increase in treatments where high amounts of scorch on the flag leaf were detected. The application of late N had the opposite effect in trials with minimum amounts of scorch.

Soil applications of this type of urea may result in increased efficiency as evidenced in the literature and as shown with a higher grain N recovery at Ardclough in 1998, but further work is necessary before a definite conclusion is reached on the efficiency of soil-applied liquid Flex urea (N18).

CONCLUSIONS

- In soils where P is low, the application of P fertiliser is likely to give increased plant uptake and higher yields in the year of application. In these situations, formulation of P as urea phosphate (as in the Flex system) gives the same results as conventional granular superphosphate when applied to the soil surface, in terms of recovery of P by the crop, grain yield and grain quality regardless of soil type. Placement of liquid urea phosphate may give better results but this requires further research.

- In field comparisons of the main soil-applied liquid Flex source of N, i.e. N24 (urea with the addition of a standard level of acid and metal salts) with conventional N fertilisers, i.e. CAN and urea, N24 may give poorer performance than CAN and granular urea in warm dry conditions due to insufficient inhibition to substantially reduce ammonia volatilisation. In wet conditions, the slow release of N from inhibited urea may reduce the potential loss from leaching or denitrification, and lead to a better performance than CAN or urea.

- With regard to complete fertiliser systems, the necessity for Flex P applications to be accompanied by roughly similar amounts of N (because of the bond between N and P in urea phosphate) leads to inefficient fertiliser use in some situations. In soils with low P reserves, the early application of P may be essential to obtain maximum response. The N that accompanies the early application of P as urea phosphate is likely to be lost through leaching. Optimum use of N and P cannot be achieved in this situation.

- The additional product of the Flex system, i.e. Liquid Flex urea - N18, applied as a foliar spray, is no more efficient than liquid urea as a late N source in terms of grain yield, protein content or N recovery in grain. The Flex urea has the disadvantage of giving higher scorch levels than conventional liquid urea.

- The Flex system offers some practical advantages over solid fertilisers. As a complete liquid system, the handling, storage and application of the fertiliser can be carried out at a lower labour and machinery cost. This is especially the case on larger farms. The liquid fertiliser can also be applied more evenly and precisely, and application is less weather-dependent, while specific formulations can be tailor-made for given crop requirements ensuring maximum efficiency and greater environmental benefits.

Do Reduced Input Systems Give Greater Profits?

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INTRODUCTION

An experiment to compare cereal input systems was designed in 1994 against the changing background in agriculture in general, and tillage in particular, over the last few decades. In the 1970s and early 1980s, with few constraints on agricultural production, the emphasis was placed on high input and high output systems. With high prices for cereals, together with increasing prices, this gave rise to increasing profits for the efficient cereal producer. However, towards the end of the 1980s, the ever-increasing grain mountain, the threat of reduced prices, together with the growing concerns of the possible detrimental effects of the intensive use of fertiliser and crop protection chemicals, brought a greater emphasis on the production of quality food.

The increased emphasis on the production of quality food, in an environmentally-friendly way, increased the need for information on the impact of reduced inputs on grain yields, grain quality, unit costs and the profitability of the various cereal enterprises grown in different rotations, when compared with one another and with other farm enterprises.

Experimental

The experiment is both large-scale and long-term. It is large-scale because each plot, by experimental standards, is large (30m x 12.5m) for two reasons: firstly, so that crop treatments can be mechanised to the maximum, and secondly so that the results are applicable at farm level. It is large (total area of experiment covers 6 hectares) because each of the crop rotations is grown each year to eliminate seasonal variation. The experiment is of necessity long-term because more than one rotation cycle is essential to fully assess the impact of crop rotations. Each year, however, the impact of the conventional and reduced input systems on the various cereal crops can be assessed.

This long-term experiment, which was commenced in September 1994, compares the effect of
(i) a conventional high-input system with (ii) a reduced-input system
on the yield and quality of winter wheat and winter barley when grown

(a) in a non-cereal break-crop rotation with spring barley
(b) in a continuous cereal rotation with winter oats, and

(c) continuous monoculture

The experiment is sited on the medium-heavy textured limestone soil at Knockbeg, Co. Laois (Knockbeg Series). Winter wheat (cv. Brigadier in the conventional system and cv. Ritmo in the reduced system), winter barley (cv. Regina) and spring barley (cv. Cooper) were grown as

(a) **Break-crop cereals** in the following rotation:

1. Winter beans
2. Winter wheat
3. Spring barley
4. Turnip rape
5. Winter barley

To eliminate the effects of seasonal factors on crop returns, all the five crops in the rotation were sown and harvested each year.

(b) **Rotation cereals** as follow:

6. Winter wheat
7. Winter barley
8. Winter oats

Similarly, to eliminate the effects of seasonal factors on crop returns, each of the three crops in the rotation were grown each year.

(c) **Cereal monoculture** as follows:

9. Winter wheat (continuous)
10. Winter barley (continuous)

The winter wheat, winter barley, winter oats and spring barley were grown under two input systems:

(a) **Conventional high-input system**

(b) **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 judgements and certain principles. The amounts of NPK applied to the various cereal crops are set out in Table 1.

Table 1: Nitrogen phosphorus and potassium application rates, 1996

Crop	Input system	Nitrogen (kg/ha)	P & K (kg/ha)
Winter wheat	Conventional	225	432 (0.7.30 NPK)
	Reduced	188	222 (Kcl)*
Winter barley	Conventional	188	371 (0.7.30 NPK)
	Reduced	150	222 (Kcl)
Winter oats	Conventional	138	371 (0.7.30 NPK)
	Reduced	100	222 (Kcl)
Spring barley	Conventional	138	432 (18.6.12 NPK)
	Reduced	105	519 (20.0.15 NPK)

*Muriate of potash

The amount of N applied was generally 37.5 kg/ha (30 units/acre) lower on the reduced input system except in the case of malting barley (reduced by 32.5 kg or 26 units/acre). All cereals were treated with the required amounts of potassium because K levels in the soil were low but no phosphorus was applied to the reduced input system because of the excessively high P levels (18 ppm+) in the soil.

It was decided, on principle, that the reduced input system would be given a maximum of half rate (or less) of the conventional pesticides applied to control BYDV, weeds, leaf diseases and lodging.

Full costs of the inputs were carried out for each of the four years (1996-99), (Table 2) and were based on the actual input costs at three sample points (Cork, Carlow and Meath). Gross income for the winter cereals included the income from grain sales plus area-aid and was based on the actual prices obtained at the same three sample points, while the income from malting barley was based on Minch Malt's agreement with growers. Straw income was based on actual price available ex Oak Park farm sales. Machinery and other costs were based on Crop Costs and Returns compiled by J. O'Mahony, Teagasc.

Table 2: Variable input costs for conventional and reduced input systems for the different cereals groups (1996-99)

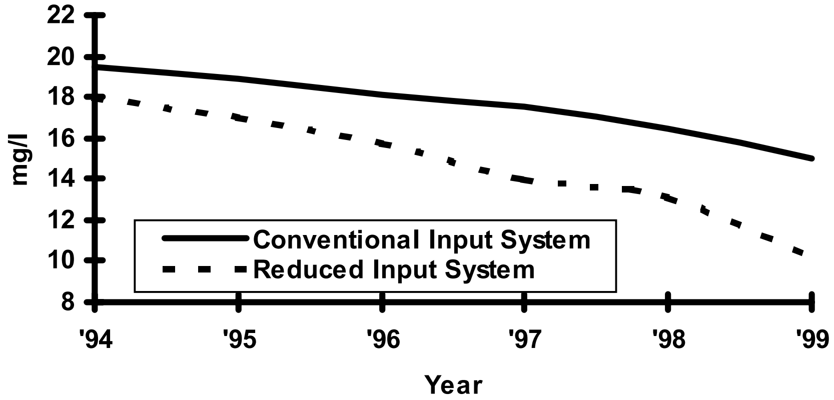
Crop	Treatments (Rotation)	Conventional Inputs					Reduced Inputs				
		Input costs (£/ha) **									
		'96	'97	'98	'99	Mean	'96	'97	'98	'99	Mean
Winter Wheat	Mean*	383	431	387	442	**411**	286	286	273	316	**290**
Winter Barley	Mean*	344	342	334	354	**344**	242	228	228	235	**233**
Winter Oats	Rotation	351	330	324	325	**333**	257	229	198	222	**227**
Spring Barley	Break-Crop	221	224	186	242	**218**	161	157	141	175	**158**

*****Mean of three treatments ******Cost of seeds, fertiliser and pesticides including interest

RESULTS

Soil Fertility

Soil phosphorus (P) levels were generally very high (+18 mg/l) when the experiment commenced in 1994, while potassium (K) was low (80-90 mg/l). In 1999 the soil P values had dropped considerably, ranging from 4-34 mg/l with only 12% of the samples over 18 mg/l while 32% were under 10 mg/l. Despite the application of the perceived requirements of P to the conventionally treated crops, residual P levels have fallen from a mean value of 19.5 to 15 mg/l over the 5-year period, 1994-1999 (Figure 1). On the other hand, the levels have dropped from 18 to 10 mg/l in the reduced input system where no phosphorus was applied



over the five years. There had been little change in soil pH over the 5-year period (Figure 2).

Fig. 1: Mean P levels of conventional and reduced input systems over 5-year period 1994-99

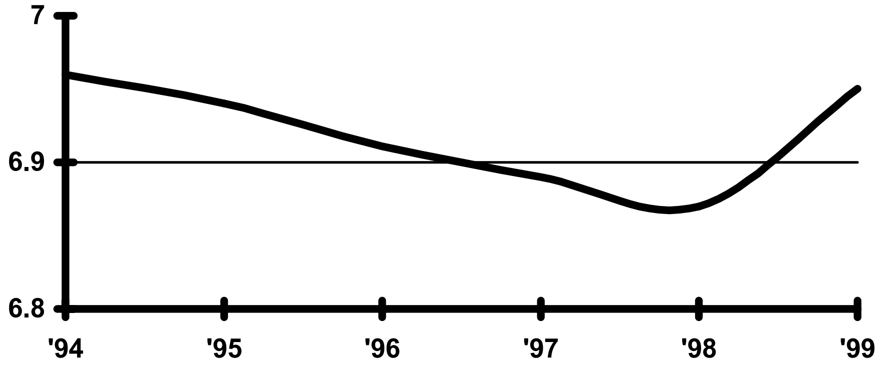


Fig. 2: Mean pH of the experimental site Knockbeg over five year period 1994-999

Mean pH values fell slightly in 1997 and 1998 but the mean pH was restored by the application of lime (10 t/ha) in autumn 1998 to a portion of the experimental area (half of block 4) where pH values were initially lower than the rest of the field. Similarly there has been little change in residual soil K levels over the 5-year period.

Grain Yield

Winter wheat consistently gave the greatest yields over the 4-year period, 1996-99 (Table 3). Mean grain yields were greater than 10 tonne per hectare in all treatments. The reduced input system gave lower mean yields than the conventional system but the reduction was less than 5% (0.5 t/ha).

Table 3: Effect of conventional and reduced input systems on the grain yield of cereals grown in different rotations (1996-99)

Crop	Treatments (Rotation)	Conventional Inputs					Reduced Inputs				
		Grain Yield (t/ha at 15% DM)									
		'96	**'97**	**'98**	**'99**	**Mean**	**'96**	**'97**	**'98**	**'99**	**Mean**
Winter Wheat	Break-Crop	9.49	12.95	8.91	10.39	**10.44**	9.05	12.21	9.20	9.79	**10.06**
	Rotation	10.13	13.30	9.75	10.66	**10.96**	9.56	12.43	9.11	9.91	**10.25**
	Monoculture	9.88	12.73	9.05	10.18	**10.46**	9.90	12.16	8.53	9.56	**10.04**
	Mean	9.84	13.00	9.24	10.41	**10.62**	9.51	12.27	8.95	9.75	**10.12**
Winter Barley	Break-Crop	8.78	9.32	8.30	9.98	**9.10**	8.06	7.99	7.52	9.31	**8.22**
	Rotation	9.07	9.09	9.08	9.45	**9.17**	8.07	7.39	7.70	8.39	**7.89**
	Monoculture	8.75	9.15	9.26	9.26	**9.11**	7.35	7.51	8.13	8.60	**7.90**
	Mean	8.86	9.19	8.88	9.56	**9.12**	7.83	7.63	7.78	8.76	**8.00**
Winter Oats	Rotation	9.35	10.31	5.47	9.61	**8.72**	8.54	9.28	5.49	8.44	**7.74**
Spring Barley	Break-Crop	7.17	7.39	5.61	7.62	**6.91**	6.10	6.86	4.70	6.68	**6.28**

Winter wheat, grown in rotation, after winter oats gave significantly greater yields than the other two treatments in both systems, conventional and reduced. The increased amount of lodging in break-crop winter wheat may have reduced the grain yield in that treatment (Table 4). However, in 1997 and 1999, when there was little or no lodging, the rotation winter wheat still gave the largest yields.

The conventional winter barley input system gave consistently greater yields than the reduced input system in all four years but there were little differences between the treatments (break-crop, rotation and monoculture). Mean yield reduction was 12%. In the two years, 1997 and 1999, when there was no lodging, yields were best after the break-crop. The small increase in leaf disease on the reduced input system (Table 5) would not account for this reduction in yield.

The grain yield of winter oats, especially under the conventional system, were consistently high (9-10t/ha) except in 1998, when severe lodging in early June, reduced grain yield enormously. The reduced input system gave a yield reduction of 10-11%.

Table 4: Effect of conventional and reduced input systems on the amount of lodging in cereals grown in different rotations (1996-99)

Crop	Treatments (Rotation)	Conventional Inputs				Reduced Inputs			
		Lodging Index							
		'96	'97	'98	'99	'96	'97	'98	'99
	Break-Crop	40	4	95	0	63	17	97	0
Winter	Rotation	1	0	78	0	0	3	95	0
Wheat	Monoculture	0	0	54	0	0	2	99	0
	Break-Crop	81	8	62	0	86	1	67	0
Winter	Rotation	69	0	0	0	58	0	17	0
Barley	Monoculture	65	0	0	0	65	0	14	0
Winter Oats	Rotation	0	65	92	0	0	24	96	0
Spring Barley	Break-Crop	0	58	0	0	0	0	0	0

Table 5: Difference in the amount of leaf necrosis due to disease recorded on the top three leaves of winter barley on the reduced and conventional input systems over the four year period (1996-99)

Year	Conventional Inputs			Reduced Inputs		
	% Disease Necrosis					
	leaf 1	leaf 2	leaf 3	leaf 1	leaf 2	leaf 3
1996	0	4	55	0	4	67
1997	0	0	4	0	1	9
1998	0	3	5	4	9	8
1999	0	7	11	0	11	15
Mean	**0**	**4**	**19**	**1**	**6**	**25**

The spring malting barley Cooper was grown in all four years but in 1997 it failed to meet malting barley standards due to sprouting as a result of the exceptionally heavy and prolonged rain over the August weekend. Yields were low in 1998 due to severe infection with the leaf spotting disease and possibly to leaching of nitrogen. The conventionally high input system gave the greatest yields in the other three years. The reduced input system gave an mean yield reduction of 9%.

Grain Quality

Reducing inputs had little affect on grain. Seasonal differences were greater than the differences between treatments or systems hectolitre weight (kph) or screenings (Tables 6 and 7). The higher levels of screenings in the winter barley reduced-input system may be due to inadequate nitrogen but it may also be due to poorer control of leaf diseases. The higher rate of N applied to the conventional input system gave higher protein levels in all crops, including malting barley (Table 8).

Table 6: Effect of conventional and reduced input systems on the hectolitre weight (kph) of cereals grown in different rotations (1996-99)

Crop	Treatments (Rotation)	Conventional Inputs					Reduced Inputs				
		Hectolitre Weight (kph)									
		'96	**'97**	**'98**	**'99**	**Mean**	**'96**	**'97**	**'98**	**'99**	**Mean**
Winter Wheat	Break-Crop	72.3	74.8	71.5	76.1	**73.7**	72.4	75.3	71.6	75.9	**73.8**
	Rotation	75.1	75.3	72.8	76.1	**74.8**	75.1	75.0	71.6	75.0	**74.2**
	Monoculture	74.8	75.4	72.9	75.6	**74.9**	75.8	74.4	69.0	74.1	**73.3**
	Mean	74.0	75.1	72.4	76.0	**74.3**	74.4	74.9	70.7	75.0	**73.8**
Winter Barley	Break-Crop	66.0	64.6	63.2	66.5	**65.1**	64.9	63.9	62.8	65.0	**64.2**
	Rotation	66.5	64.3	65.8	66.0	**65.7**	65.3	62.9	63.1	62.9	**63.8**
	Monoculture	65.9	64.6	64.3	66.9	**65.4**	64.8	63.3	63.6	64.8	**64.1**
	Mean	66.1	64.5	64.4	66.1	**65.3**	64.9	63.3	63.2	64.2	**63.9**
Winter Oats	Rotation	58.7	52.9	47.6	54.0	**53.3**	58.4	54.3	49.2	52.1	**53.5**
Spring Barley	Break-Crop	67.5	59.0	65.4	66.3	**64.6**	67.3	60.0	64.0	65.4	**64.2**

Table 7: Effect of conventional and reduced input systems on the amount of screenings (%) in cereals grown in different rotations (1996-99)

Crop	**Treatments (Rotation)**	**Conventional Inputs**					**Reduced Inputs**				
		Screenings (%)									
		'96	'97	'98	'99	**Mean**	'96	'97	'98	'99	**Mean**
	Break-Crop	2.8	0.9	1.8	2.4	**2.0**	3.0	1.0	1.5	2.9	**2.1**
Winter	Rotation	2.3	0.8	2.0	2.3	**1.9**	2.0	1.1	1.3	3.2	**1.9**
Wheat	Monoculture	2.0	0.7	1.9	2.7	**1.8**	1.8	1.1	1.5	3.6	**2.0**
	Mean	2.4	0.8	1.9	2.5	**1.9**	2.3	1.1	1.4	3.2	**2.0**
	Break-Crop	2.7	4.4	5.5	1.9	**3.6**	2.8	5.3	7.4	2.6	**4.5**
Winter	Rotation	2.4	2.3	4.4	3.1	**3.0**	3.3	3.6	5.5	4.4	**4.2**
Barley	Monoculture	2.7	2.2	3.1	2.4	**2.6**	4.6	4.2	4.3	3.0	**4.0**
	Mean	2.6	3.0	4.3	2.5	**3.1**	3.5	4.3	5.7	3.3	**4.2**
Winter Oats	Rotation	5.6	4.2	8.9	2.7	**5.4**	4.9	3.3	10.0	2.3	**5.1**
Spring Barley	Break-Crop	2.3	10.1	7.5	4.3	**6.1**	2.2	7.7	5.8	4.8	**5.1**

Table 8: Effect of conventional and reduced input systems on grain protein of cereals grown in different rotations (1996-99)

Crop	**Treatments (Rotation)**	**Conventional Inputs**					**Reduced Inputs**				
		Grain Protein (% DM)									
		'96	**'97**	**'98**	**'99**	**Mean**	**'96**	**'97**	**'98**	**'99**	**Mean**
	Break-Crop	8.8	8.8	10.0	9.4	**9.3**	8.1	8.0	8.9	9.2	**8.6**
Winter	Rotation	8.7	9.1	9.8	9.2	**9.2**	8.1	8.2	8.5	8.6	**8.4**
Wheat	Monoculture	8.6	9.0	9.2	9.2	**9.0**	7.9	8.0	8.9	8.7	**8.4**
	Mean	8.7	9.0	9.7	9.3	**9.2**	8.0	8.1	8.7	8.9	**8.4**
	Break-Crop	11.6	12.4	13.1	11.5	**12.2**	10.5	11.6	12.1	10.2	**11.1**
Winter	Rotation	11.5	11.9	12.5	11.8	**11.9**	10.5	10.9	11.8	10.0	**10.8**
Barley	Monoculture	11.8	11.6	12.7	11.2	**11.8**	10.8	11.0	11.2	9.6	**10.7**
	Mean	11.6	11.9	12.7	11.5	**11.9**	10.6	11.1	11.5	9.9	**10.8**
Winter Oats	Rotation	10.7	10.0	11.0	9.3	**10.3**	9.0	9.0	10.2	8.7	**9.2**
Spring Barley	Break-Crop	9.0	10.4	10.0	10.3	**9.9**	8.6	9.6	8.9	9.3	**9.1**

Financial Returns

Over the four years of the experiment the winter wheat gave the greatest financial returns followed by spring malting barley (Table 9). Winter wheat grown in rotation after winter oats gave slightly better returns than the other two treatments.

Table 9: Effect of conventional and reduced input systems on gross margins of cereals grown in different rotations (1996-99)

Crop	**Treatments (Rotation)**	**Conventional Inputs**	**Reduced Inputs**

		Gross margin (£ / hectare)*									
		'96	**'97**	**'98**	**'99**	**Mean**	**'96**	**'97**	**'98**	**'99**	**Mean**
Winter Wheat	Break-Crop	628	699	444	485	**564**	694	794	594	547	**657**
	Rotation	664	727	517	527	**609**	730	811	586	608	**684**
	Monoculture	638	676	451	482	**562**	767	787	531	575	**665**
	Mean	643	701	471	498	**578**	730	797	570	577	**669**
Winter Barley	Break-Crop	579	507	450	571	**527**	616	524	502	644	**571**
	Rotation	599	489	515	527	**533**	619	476	517	567	**545**
	Monoculture	566	494	532	509	**525**	546	486	556	586	**544**
	Mean	581	497	499	536	**528**	594	495	525	599	**553**
Winter Oats	Rotation	578	577	195	557	**477**	609	608	343	564	**531**
Spring Barley	Break-Crop	749	467	470	618	**576**	684	505	456	616	**565**

***** Gross income (grain, straw and area-aid) less variable and machinery input costs

Although the conventional high-input system gave greater yields that the reduced-input system the financial returns were greater from the reduced-input system (Table 9). The financial returns from the reduced input-system on winter wheat were greater in all three rotations and in all four years. The reduced input-system gave greater returns on winter oats in all four years. In the case of winter barley the reduced-input system gave greater financial returns in three years out of four with little difference between the two systems in the fourth year. However, for malting barley the conventional high-input system gave the best financial returns in three years out of four.

CONCLUSIONS

There was a gradual reduction in soil P levels over the 5-year period (1994-99) but the rate of reduction was greater under the reduced-input system, which received no P.

Winter wheat gave the greatest yields followed by winter oats and winter barley. The wheat grown in rotation after winter oats gave higher yield than wheat grown in monoculture or after the non-cereal break-crop.

The difference in yield between the two systems, conventional and reduced, was relatively small (less than 5%) for winter wheat but was much larger (9-12%) for winter barley and winter oats.

Reduced crop inputs had little or no effect on grain hectolitre weight or screenings. The increased N applied in the conventional input system increased grain protein in all cereals, including malting barley.

In the case of winter wheat the reduced-input system gave greater financial returns than the conventional system but spring malting barley gave the best returns, in three years out of four, when grown under the conventional high-input system.

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Scale and Efficiency - Key Factors For Survival

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INTRODUCTION

It may sound like a cliché, but to survive as a tillage farmer into the new millennium, there are two basic requirements; Efficiency and Scale.

Efficiency can be defined as optimising yields and optimising costs in order to maximise profits. This does not necessarily mean maximising yields and minimising costs.

Scale can be defined as operating in such as way as to make the best use of land, labour, machinery and capital. This does not necessarily mean increased acreage, but this is definitely the trend especially for full-time farmers.

In this paper, I propose to examine some of the factors that determine efficiency on tillage farms and to look at the impact of efficiency on margins. To do this, I will use an analysis of a group of intensive tillage farmers using the Tillage Profit Monitor Computer Programme.

I will then report on a survey of tillage farmers which outlines their perception of scale, what scale will be required in the future and their view of the best means of achieving scale.

Finally, as a lead-in to Dermot Forristal's paper I will give a brief overview of the various mechanisms, which may be employed to improve scale.

EFFICIENCY

This Tillage Profit Monitor analysis was carried out on 30 intensive tillage farmers, including discussion group members as well as participants in the Advanced Tillage Course at Oak Park.

Table 1 outlines the profile of the group in terms of the principal crops grown on their farms.

Table 1: Tillage Profit Monitor - crop output

	Winter Wheat	**Winter Barley**	**Malting Barley**	**Sugar Beet**
Area sown (ha)	43	33	21	20
Yield (t/ha)	9.39	7.66	6.30	64.74
Crop sales	826	693	579	1994
Other sales	84	121	104	35
Aid	274	274	274	-
Gross output	1184	1088	957	2029

Table 2 gives a break down of the material costs incurred by the group in growing these crops.

Table 2: Tillage Profit Monitor - material costs

	Winter Wheat	**Winter Barley**	**Malting Barley**	**Sugar Beet**
Seed	63	45	50	89
Fertiliser	120	105	70	195
Fungicides	118	78	63	18
Herbicides	30	30	23	152
Total	357	295	222	485

A point worth noting from Table 2 is the wide discrepancy in material costs between Winter Wheat and Malting Barley.

Table 3 shows the net margin from the various crops along with the average conacre or lease payments on that area which was rented.

Table 3: Tillage Profit Monitor - net margin

	Winter Wheat	**Winter Barley**	**Malting Barley**	**Sugar Beet**
Machinery costs	268	280	180	473
Fixed costs	383	383	288	635
Total costs	740	678	510	1120
Net margin	444	410	447	909
Average lease	285	325	275	346

Given that 1999 was a relatively good year and that this group of farmers are above average performers, margins were quite tight and this underlines the fact that many producers on rented land continue to operate on a knife-edge.

The comparative analysis is the more interesting part of this analysis and Table 4 compares the top, middle and bottom winter wheat growers within the group. The top, middle and bottom classification is based on the net margin per hectare.

Table 4: Winter wheat comparative analysis

	Top	**Middle**	**Bottom**
Yield (t/ha)	9.40	9.37	9.38
Gross output	1332	1192	1138
Materials	332	355	401
Machinery	187	245	368
Total costs	637	692	911
Net margin	702	488	170

While yields were similar for the three groups, the material costs and especially the machinery costs were higher for the middle and bottom groups.

Fungicide costs, for example, were £105/ha for the top group, £115/ha for the middle group and £126/ha for the bottom group. The net result of all of this was a massive difference in margins between the top group at £702/ha and the bottom group at £170/ha. While many factors contributed to this, machinery costs was by far the biggest factor suggesting that lack of scale was the principal driver of low net margins. Table 5 shows the comparative analysis for malting barley growers within the group.

Table 5: Malting barley comparative analysis

	Top	**Middle**	**Bottom**
Yield (t/ha)	6.78	6.25	6.11
Gross output	1014	978	899
Materials	207	199	247
Machinery	153	170	208
Total costs	429	518	578
Net margin	599	464	315

In the case of malting barley, yield does have an effect on margins between the top group and the bottom group but not as marked an effect as that of costs.

An alternative way of looking at costs and margins is in terms of cost per tonne. Based on what is currently being achieved by our top growers and also in the context of price reductions as a result of Agenda 2000, we in Teagasc have set an ambitious target for growers to produce grain at £65/tonne (excluding land rental charges). Table 6 gives a breakdown of the costs per tonne for the Winter Wheat and Spring Barley crops.

Table 6: Cost per tonne - comparative analysis

	Top	**Middle**	**Bottom**
Winter Wheat	67.7	73.8	97.1
Malting Barley	63.3	82.9	94.6

It is clear from the table that our top performers are more than meeting the targets while those in the bottom group will be using a sizeable portion of their arable aid to meet the costs of growing the crop.

SCALE

Moving on now to scale and it appears that 'size definitely matters' when it comes to tillage farming in the new millennium. This is the clear message coming from a study of tillage farmers conducted during 1999.

The study of 154 large tillage farms found that, while the average area currently farmed among this group is 114 ha, they felt that this would need to expand to over 200 ha if they are to survive in the new millennium (see Table 7).

Table 7: Comparison of tillage area currently farmed with that required for the future

	Current area farmed (ha)	**Area required in the future (ha)**
Total area farmed	114	214
Own land	68	110
Conacre	46	104

Understandably the smaller farmers surveyed (50 - 80 ha) envisaged the biggest increase, hoping for a 291% increase.

The middle category (80 - 160 ha) felt they needed to double their farm size, while the largest category (above 160 ha), were talking about a 10% increase in farm size.

Problems Facing Tillage Farmers

When asked about the biggest problems facing tillage farmers in the future, falling margins was mentioned by most farmers (91%) while labour availability was seen as the second biggest problem (Table 8).

Table 8: Biggest problems facing tillage farmers in the new millennium

Problem	Percentage mentioned as problem
Falling margins	91%
Labour availability	72%
Achieving scale	69%
Land availability	53%
Achieving quality grain	5%

Achieving scale and availability of land were also seen as big problems while achieving quality grain was not seen as a big issue.

Options for Achieving Scale

When questioned about the best means of achieving scale, the conacre system, which to-date has been by far the most popular method, ranked only fifth (see Table 9).

Table 9: Options for achieving scale on tillage farms

Option	Percentage mentioned as option
Leasing	62%
Share-farming	47%
Contracting	46%
Inter-farm contracting	40%
Conacre	37%
Partnerships	25%
Land purchase	14%
Other	4%
Don’t know	3%

Leasing was the most popular option and was mentioned by over 60% of respondents as a good way of improving scale.

Share-farming, contracting and inter-farm contracting, which is another way of sharing machinery, were also high on the list while, not surprisingly, the current high price of land kept land purchase well down the list.

Partnerships were also well down the list but there was some confusion in respondents minds as to the implications of partnerships and how they might differ from share-farming agreements.

Membership of REPS

Apart from improving scale of operation, joining REPS is the other main option open to tillage farmers to improve their viability.

The questions on REPS in the survey were open to all tillage farmers regardless of size (a total of 405 respondents) and it was found that 26% of these surveyed are currently in REPS (see Table 10).

Table 10: Membership of REPS

		Area of cereals (acres)			
	Total	15-40	40-80	80-125	125+
Currently in REPS	26%	29%	29%	24%	8%
Currently not in REPS	74%	71%	71%	76%	92%

Not surprisingly the percentage in REPS varied from 29% in the smaller size categories to only 8% in the size category above 125 acres.

A regional analysis shows that the lowest REPS membership is in the Dublin/Louth/Meath region where a lot of big tillage farmers are located. The highest membership was in the Kilkenny/Tipperary/Waterford region.

Further analysis shows that a much higher percentage of non-participants have winter cereals compared with participants in REPS.

When non-participants were asked about their intention of joining REPS only 23% said they planned to join.

Again, those planning to join REPS were concentrated in the smaller size categorises and had less winter cereals.

The principal drawbacks to joining REPS as perceived by all participants are outlined in Table 11.

Table 11: Principal drawbacks to joining REPS among tillage farmers

Drawback	Percentage mentioned as drawback
Fertiliser limits	43%
Restrictions/bureaucracy	25%
Limit on stocking density	24%
One hundred acre limit	17%
Headland restrictions	17%
Ban on growth regulators	15%
Additional compliance cost	12%
Pollution control costs	11%
Paperwork/records	9%
Wouldn't pay	7%
Limit on trimming hedges	5%
Restricted use of slurry/FYM	5%
Fencing costs	5%
Severity of penalties	5%
Doesn't suit intensive growers	5%
Others	33%

The fertiliser limit was seen as the main drawback to joining REPS among tillage farmers with restrictions on stocking density and farm size also major drawbacks.

OPTIONS FOR ACHIEVING SCALE

Dermot Forristal will be looking at some of the options in detail but I will give a brief overview of each of the options outlined earlier.

Conacre is far the commonest mechanism currently employed.

Advantages: Feasibility for landowner.
Disadvantages: Makes planning difficult.
No incentive to maintain land.

Land Purchase is not a runner at present.

Advantages: Creating an asset base.
Disadvantages: Very low return on investment (3% at present).

Leasing was a rarity before REPS and the Retirement Scheme but is now generally accepted.

Advantages:	Facilitates planning. Incentive to maintain land. Tax advantages in certain situations.
Disadvantages:	May prove too expensive. Lack of flexibility for landowner.

Contracting is often carried on to justify over-mechanisation and to utilise surplus labour.

Advantages:	Generates extra income. Utilises existing machinery and skills.
Disadvantages:	May lead to neglect of one's own crops.

Inter-farm contracting is where two or more farmers work together to achieve scale in order to justify certain items of equipment e.g. two 80 hectare farmers working together, one with a plough and the other with a one-pass.

Advantages:	Scale can be achieved with reduced machinery costs.
Disadvantages:	"Who cuts first?"

Share farming is where, for example, a larger full-time farmer provides machinery and expertise to a part-time operator who wants to be involved in farming and participate in REPS. Profits are shared.

Advantages:	Incentive for both partners to do a good job. REPS utilised and possible capping of payments avoided.
Disadvantages:	May be difficult to monitor.

Partnership models can vary but full partnerships involve everything being pooled.

Advantages:	Best economic decisions can be made because it doesn't matter 'who cuts first'. Scale economies can be achieved freeing up surplus labour.
Disadvantages:	Quota / Premia / REPS entitlements. Very difficult to get it right at the beginning.

CONCLUSIONS

- Efficiency and scale are equally vital components for the survival for a vibrant tillage sector in this country.

- Efficiency involves optimising yield and costs so that, at the very least, you the grower can hold on to your arable aid payment. This may involve producing grain at £65/ton and, as we have seen, only our very top growers are achieving this.

- Scale will also play a key role in achieving this target. Many of you will continue to grow the business with 200 ha being the target, many of you have set. More of you will farm what you have more efficiently using the freed up time to generate additional income from alternative sources.

- There are a variety of mechanisms, which you must consider to enable you to achieve efficiency and scale. Dermot Forristal in his paper will show how the numbers stack up for some of these option.

Tackling the Machinery, Labour and Scale Problems

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INTRODUCTION

Factors which influence profitability and the future structure of tillage farming continue to change. Cereal prices are decreasing while direct support may not be maintained at current levels into the future. Another factor, the availability of off-farm employment, is now exerting an influence. The cost and availability of hired labour is causing problems, while the supply of well-paid employment is attracting many away from full-time farming.

Change should force a close examination of individual farm business. Cost structures and options for the future must be carefully examined. Machinery costs, the interaction between machinery, labour and scale, and the long-term nature of machinery decisions, combine to make the evaluation of mechanisation a critical factor in this process.

Competitiveness and Costs

Where product price is increasingly being determined by world market price, European producers must now strive to be competitive with world market suppliers. Local market forces and EU support schemes will continue to support farm income, but the objective must be to produce quality grain at low cost. Production costs can be divided into a number of categories:

- Variable costs
- Machinery costs
- Labour costs
- Other overhead costs

Variable costs, i.e. those relating to seed, fertiliser and agrochemical use, have been studied and, provided good agronomic research on the use of these inputs is available, the economic benefit of their use can be determined.

Machinery and labour are difficult to cost and their effect on crop production is difficult to value. Previous Oak Park research has highlighted the extent and variability of machinery costs on tillage farms. This study (completed 5 years ago) showed average machinery costs to be £194/ha with a range of from £93 to £340/ha. The influence of factors, such as machine capacity, replacement age, purchase as new/second-hand and operating scale, was evident. Labour associated with the use and on-farm maintenance of machinery was not examined in this study. Labour and machinery are intrinsically linked on tillage farms, as most labour is associated with the use of machinery. The choice of machinery system in terms of machine capacity, machine system and indeed the replacement age of the machine will influence labour requirement.

Other overhead costs include items such as office, car phone etc., which cannot be easily attributable to any other cost category.

Scale

It is a commonly held view that scale must be increased to maintain margins when product prices decline. This, of course, is only true if an increase in scale can be achieved at a reasonable cost. There are two aspects to scale which influence margins.

- ♦ An increase in scale gives more area from which to generate profit.
- ♦ Economies-of-scale usually result in lower production costs per unit area.

Machinery and labour are the inputs most influenced by scale. Many competing countries producing grain for the world market have much larger production units than Ireland, with potential scale advantages. While scale is not the only factor influencing competitiveness, the benefits it offers should be pursued.

Methods of Achieving the Benefits of Scale

The traditional methods of achieving scale have been the acquisition of land by the grower through land purchase or long- or short-term rental. This potentially gives the grower access to both aspects of benefits of scale. In practice, the cost of land acquisition often negates the benefit of the increased land area, with the only extra margin, if any, coming from economies-of-scale, i.e. reduced production costs. Share farming in many situations is similar to renting, except the landowner takes some of the risk with the grower. High prices and the imbalance between supply and demand for land make the pursuit of scale difficult, risky, and often uneconomic.

The alternative approach is to achieve the benefits of scale in terms of reduced production costs without necessarily increasing the area farmed by individual growers. For example, using machinery over large areas, either through partnerships or contracting arrangements, will reduce labour and machinery costs. This approach will not guarantee farm incomes - if market prices and support drop, farm income will drop - but it should allow the production costs to be competitive on a per tonne or per unit area basis. This is the most important target to achieve in our grain production industry. Whether growers are operating large or small units, low production costs are essential. If smaller growers cannot achieve adequate income because of their size, then alternative income sources must be pursued. Environmental support schemes (e.g. REPS) offer limited scope, but off-farm employment will be necessary in many situations.

Labour

In the past the cost of labour has not been considered on many Irish tillage farms, as the farmer's own labour and family labour have been the major supply source. It was often argued that the farmer's own labour should not be costed, as his time was available. This approach had an impact on the machinery systems deployed and their cost. Older machines, which required considerable repair and maintenance time, could be operated quite inexpensively by farmers with good mechanical ability. Traditional sowing/cultivation systems or low output systems, which required a high labour input, were made feasible by the availability of family labour and/or inexpensive casual labour.

The situation has changed dramatically in recent years. The availability of flexible labour, either from family or casual sources, has decreased significantly. Relative farm incomes have dropped and increasing numbers of farmers are participating in off-farm employment. Labour is now a significant factor in crop production and must be costed.

Machine Developments

Developments in machinery continue, with improvements in technology and increases in size and work capacity. These changes offer scope for reduced crop production costs if these machines are deployed over large areas. To remain competitive, these systems must be adopted and mechanisms must be put in place to allow them to be deployed on a sufficient scale to achieve low costs.

SCALE, MACHINERY AND LABOUR

The benefits of scale must be pursued to improve competitiveness. In the past short-term rental was the most commonly practised method. There are other development models available. The particular model adopted at farm level would influence production costs, labour requirement and profit. At industry level, the models adopted would have implications for the structure of the industry and its long-term stability. In this country, the system chosen could have environmental and social implications. The possible development models include:

- Land purchase
- Short term rent / conacre
- Long term rent / leasing
- Share farming
- Using contractors
- Inter-farm contracting
- Machinery rings
- Farm partnerships

Many of these are not distinct categories. The implications for machinery and labour are similar with many of these models. The first four models are very similar. One set of machinery and one manager could control the whole operation. The last four facilitate a more flexible approach, with the original farmers inputting labour and machinery if they so desire.

Many factors will influence the choice of model on individual farms. Each situation must be examined individually. A key component of this process would be an examination of machinery cost and labour implications. In the remainder of this paper, hypothetical case studies are used to demonstrate the effect of scale on machinery costs and labour. Although only self-ownership, contracting and partnerships are discussed, the implications for other development models are also evident.

Case Studies

Three hypothetical farms were evaluated to demonstrate the effect of scale and the choice of mechanisation options on machinery costs and labour. For each farm, costs and labour associated with the use of machinery were evaluated using the Oak Park machinery cost program. This program calculates the average annual running cost of individual machines based on the type of machine, its age at purchase and sale, and its use level. The farm sizes selected were 50 ha, 100 ha and 150 ha. The 50 ha farm was assumed to grow spring barley only, while the larger farms produced winter cereals.

The first option costed on all farms was an appropriate complement of owned machinery for all operations. Details of the machine types and their replacement policy are given in Table 1. An alternative policy, where some of the mechanisation complement is sourced off the farm, e.g. by using a contractor, is also costed. Details of these options are given in Table 2.

Table 1: Machines and replacement cycles on case study farms

	50 ha-1		100 ha-1		200 ha-1	
	Own machines	**Rep. cycle**	**Own machines**	**Rep. cycle**	**Own machines**	**Rep. cycle**
Tractors	75 kW 4WD	5-10[1]	82 kW 4WD	0-12	90 kW 4WD	0-15
	61 kW	8-10	82 kW 4WD	6-10	82 kW 4WD	6-12
	55 kW	12-8	55 kW	12-8	82 kW 4WD	10-10
					55 kW	8-12
Cultivation	3F rev. plough	0-12	4F rev. plough	0-10	4F rev. plough	0-10
	4 m cultivator	0-12	3 m one-pass	0-10	4F rev. plough	0-10
	4 m drill	6-12	Roller	0-12	3 m one-pass	0-6
	6 m roller	0-15			Roller	0-10
Other	12 m sprayer	0-10	15 m sprayer	0-8	21 m sprayer	0-15
	12 m spreader	0-10	15 m spreader	0-8	21 m spreader	0-8
	Combine (small)	10-12	Combine	6-12	Combine	0-15
	Trailers (2)	0-20	Trailers (2)	0-20	Trailers (3)	0-15

Notes: [1]5-10: Machine purchased at 5 years old, replaced after a further 10 years

Table 2: Option 2 (use of contractor) on case study farms

	50 ha-2	**100 ha-2**	**200 ha-2**
Contractor operations	Plough	Cultivate	50% of ploughing
	Cultivate	Sow	
	Sow	Harvest	
	Harvest + haul		

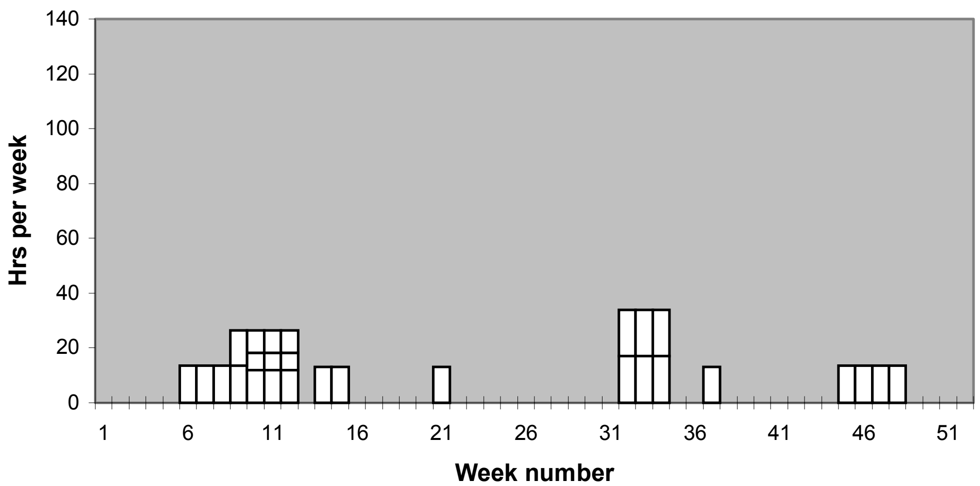
The average annual costs for these mechanisation policies were calculated and are presented in Table 3. This table also shows the amount of labour required to operate the machines. Labour was calculated as the machine operating time in the field with an additional 25% added to cover transport to the field etc. Labour per hectare farmed is also shown. Where contractors were used, the cost of their labour is included in the contracting charge, but their input is not included in the hour value in Table 3. It is difficult to estimate the cost of labour. In this example a notional charge of £8/hour was levied on the labour values. While this may appear excessive, it is likely that more time than the hours indicated would be needed to cover for maintenance/breakdowns, broken weather etc. Also the full cost of employment (tax, insurance etc.) is probably more accurately reflected with this high rate.

Table 3: Machine and labour costs on 3 case study farms

Farm	50 ha-1	50 ha-2	100 ha-1	100 ha-2	200 ha-1	200 ha-2
Machine costs/ha (£)	267	232	250	234	214	208
(Contracting (£))	*(4)*	*(203)*	*(3)*	*(124)*	*(3)*	*(22)*
No. of machines (n)	12	3	14	11	16	14
Machine labour (hr)	356	65	669	481	1188	1026
Labour/ha (hr)	7.1	1.3	6.7	4.8	5.9	5.1
Labour costs/ha @ £8/hr (£)	57	10	54	39	48	41
Total cost/ha (£)	324	243	304	273	261	249

While the quantity of labour required may not be large, its distribution over the year can cause difficulties. Depending on the farming system, areas to be covered and machine capabilities, a pattern of labour requirements through the year can be estimated. The labour requirement patterns for the options evaluated on the three farms are given in Figures 1-3. These graphs show the likely demands in hours per week for each individual task over the year. They clearly illustrate peak periods, where tasks must be carried out simultaneously.

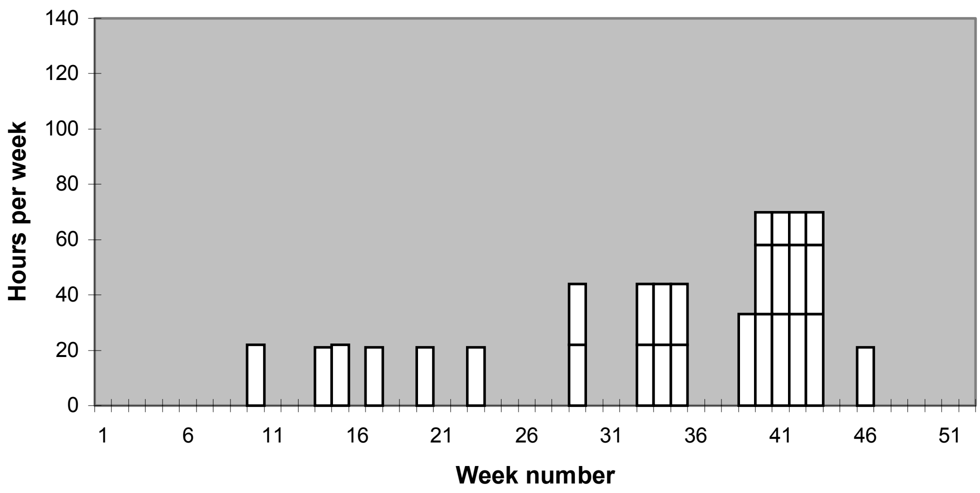
The 50 ha farm operating its own machinery has the highest machinery costs and labour demands, despite growing just spring barley. The high machinery cost figure of £267/ha increases to £324/ha when machine-operating labour is charged at £8/hr. While it could be argued that the farmer's own labour and family labour contribute much or most of this, the availability of alternative employment and the increasing need for off-farm income must be considered. By using a contractor for all operations, excluding fertiliser spreading and spraying, machinery costs can be reduced by approximately £35/ha. If labour costs are included, using a contractor brings the saving to £80/ha. This option assumes that a contractor service is available at a reasonable cost. Many contractors are currently experiencing labour difficulties which may impact on the quality and cost of their services in the future. The labour pattern graph shows the relatively small labour input required, but many operations



need to be carried out at the same time (Figure 1).

Fig. 1: Labour pattern - 50 ha own machinery

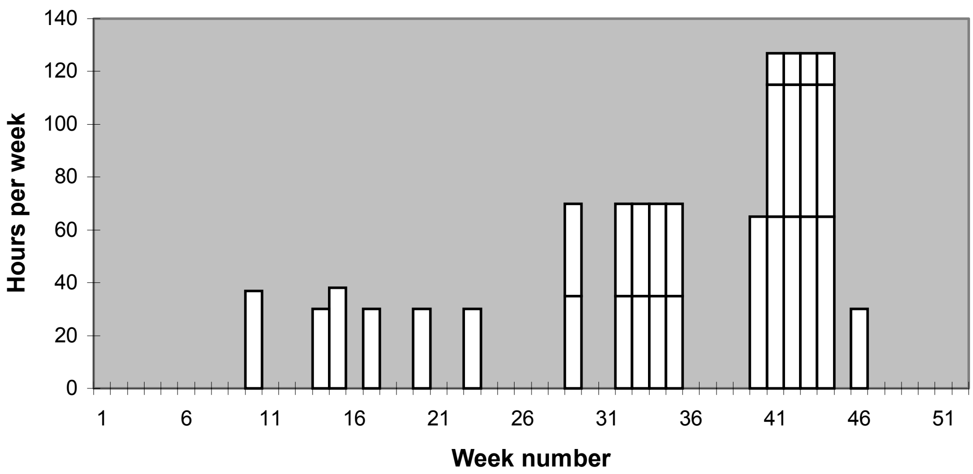
The 100 ha winter cereal farm is more difficult to deal with in many ways. Owning the machines listed in Table 1 incurs a cost of £250 before labour is charged. This rises to £304/ha with all labour costed. Using a contractor for cultivation/sowing and for combining reduces the costs to £234/ha before labour and £273/ha including labour. It is worth noting that the per-hectare costs are not as competitive with this option as with the more complete contracting option on the 50 ha farm. Winter cereals have slightly higher machinery costs. This also indicates the competitiveness of current contractor charges and also the need to carefully match the machinery owned with the area being worked. Careful adjustment to the capacity and replacement cycle of the machines should allow lower costs to be achieved on this farm. Labour demands are higher on this farm with many operations competing for labour in the autumn (Figure 2).



Note: Different bar segments indicate individual machinery operations

Fig. 2: Labour pattern - 100 ha own machinery

Costs on the 200 ha unit are substantially less than the two small farms where all owned machinery is costed. The effect of scale is obvious. This farm initially used two tractors with four-furrow ploughs for primary cultivation. Hiring in a contractor instead of one of the owned ploughs reduced machinery costs by £6/ha, but when labour is considered the saving increased to £12.52/ha. Labour peaks are quite prominent at the ploughing / sowing period. The use of two ploughing units contributes to this (Figure 3).



Note: Different bar segments indicate individual machinery operations

Fig. 3: Labour pattern - 200 ha own machinery

Scale and Contractor Use

Overall, the three sample farms clearly show the benefits of scale where the farms own their own machinery. As scale increases, machinery and labour costs decrease. The benefit of using contractors depends on the particular situation. They do have a role to play particularly where labour is valued. The 50 ha farm becomes quite competitive when contractors are used. Two notes of caution are necessary however. The machinery cost program tends to overestimate actual costs because of cautious costing methodolgy. In many situations the actual farm machinery costs may be lower. Secondly, the long-term availability of reliable contractor services at the rate used in these calculations may be in doubt because of the current labour situation and the availability of similar work in the construction industry.

Inter-farm Contracting

One of the most practical methods of gaining economics of scale in machinery use and utilising labour efficiently is the adoption of inter-farm contracting. This allows individual farmers to specialise in one or two machinery operations and to provide those services to other farmers on a contracting basis. This system was proposed and described in previous tillage crops papers (1996 and 1998) and it is practised by quite a few farmers. It can be particularly useful where the farmer providing the service wants to utilise his own labour. Payment is usually on the basis of a local contract charge, although often only a balancing payment is required if farmers work for each other. Typical examples would be where a farmer ploughs for himself and his neighbour, while the neighbour uses his one-pass machine on both farms. The combinations and permutations are endless and of course the divisions between inter-farm contracting and full-scale contracting or indeed partnerships are not clear-cut.

The one man, one tractor approach typifies this arrangement. In other countries, this type of service is facilitated by machinery rings.

Partnerships

Partnerships are arrangements where two or more farmers work together in some aspects of their operation. In a complete partnership two farmers could farm their land as one with income divided on the basis of their inputs into the partnership (capital, labour etc). In a less complete partnership, a machinery partnership could be formed where all (or some) machinery would be owned and operated on a partnership basis on the partner's farms.

The three sample farms, which have been costed individually, were evaluated in a partnership context where the machinery is selected for and operated on a single 350ha basis.
The first option that was evaluated was a conventional machinery system with a mix of machines outlined in Table 4. The labour and cost associated with this system are compared with those of the three farms operating separately in Table 5. The cost attributed to the three farms operating separately are the combined costs of the three farms divided by the total area (350ha). The costs for owned machinery and the second option, which included contractor use, are both given. It's clear that economies of scale ensure that the 350 ha partnership system has lower machinery and labour costs than a combination of the individual farms.

Table 4: Machine details on 350 ha partnership

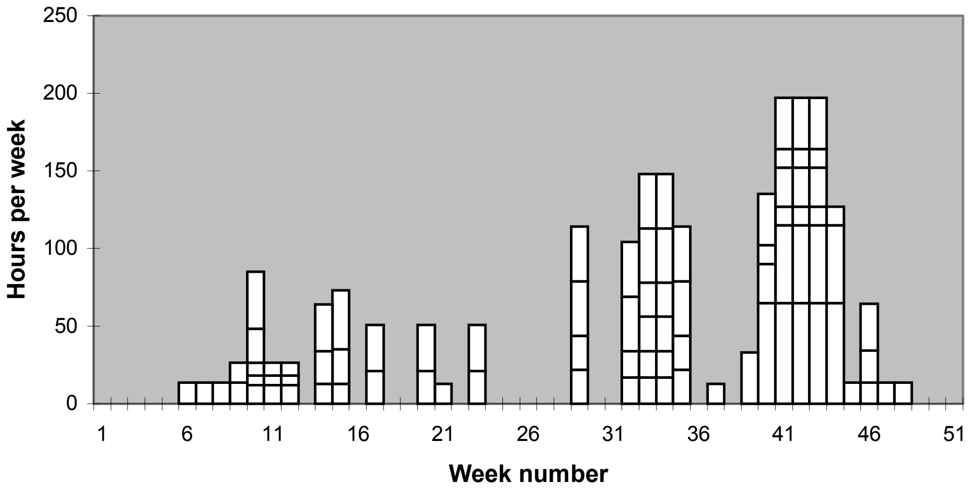
	Machine	**Replacement cycle**
Tractors	120kW 4WD	6-12
	97 kW 4WD	0-12
	82 kW 4WD	0-12
	75 kW 2WD	8-10
Cultivation/Sowing	3 m one-pass	0-4
	6f rev. plough	0-10
	Roller	0-10
Other	Combine	0-12
	Sprayer 24 m	0-8
	Trailer (3)	0-15

Table 5: Partnership costs Vs Individual costs

	Individual costs (own machinery)	Individual costs (option 2)	Partnership
Machinery costs/ha (£)	231.81	218.74	186.66
Labour total (hr)	2213	1572*	1669
Total costs (£/ha)	282.39	254.66	224.80

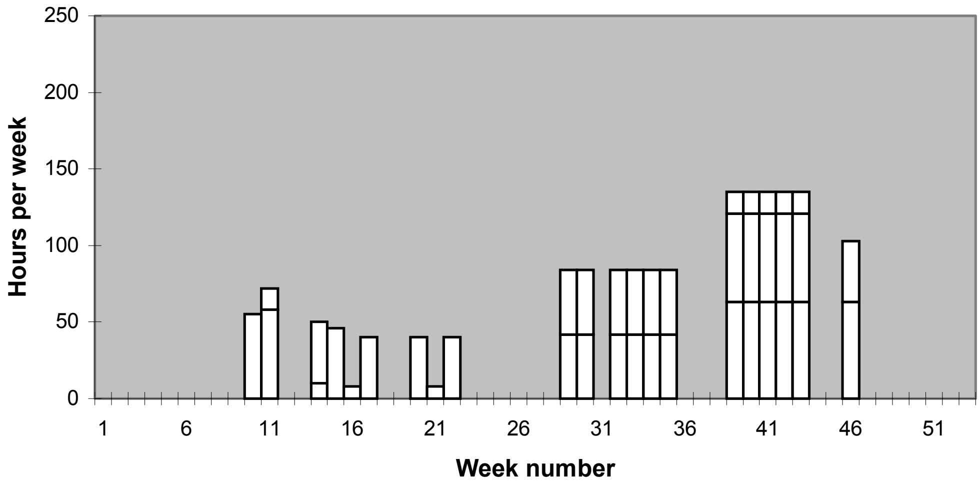
* Not including contractors labour

The partnership arrangement also had significantly lower labour demands than the individual farms owning their own machines. In particular the distribution of labour tasks was markedly different (Figures 4 and 5). The number of operations to be carried out on the separate farms was much greater at the peak cultivation / sowing time, where two of the three farms were trying to establish crops at the same time. While partnerships and inter-farm contracting have advantages, there are potential problems with both systems. Scheduling of operations (e.g. what crops are harvested first) can, in particular, be difficult. These potential difficulties must be considered and mechanisms should be put in place to avoid them becoming serious problems.



Note: Different bar segments indicate individual machinery operations

Fig. 4: Labour pattern - all 3 farms working separately



Note: Different bar segments indicate individual machinery operations

Fig.: 5: Labour pattern - 350 ha partnership

Alternative Mechanisation Systems

Farming on a larger scale allows alternative labour efficient mechanisation systems, with relatively high capital costs to be considered. Two such systems were evaluated on the basis of a 350 ha partnership. The first system substituted a reduced cultivation drill, capable of sowing into partially cultivated seedbeds, for the powered one-pass. A separate heavy furrow press was also added to this system. The second system evaluated in Table 6 is a minimum cultivation technique which uses one pass of a heavy disc combined with a press and roller, instead of ploughing. After a stale seedbed interval, the crop is sown with a minimum tillage drill. The eco-tillage concept uses this type of machinery system. The final comparison in this table is the conventional system with ploughing carried out by contractor (Standard-2).

Table 6: Costs of alternative mechanisation systems on a 350 ha partnership farm

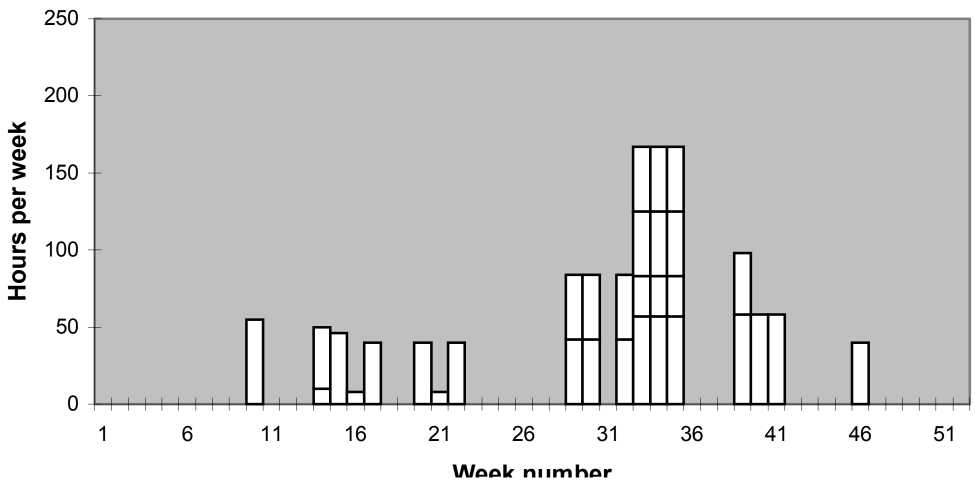
	Standard	Standard-2	Vaderstad	Eco tillage
Machinery costs/ha (£)	186.66	186.87	176.25	162.37
Number of machines (n)	14	12	15	15
Machine labour (hr)	1669	1289*	1600	1284
Labour/ha (hr)	4.77	3.68	4.57	3.66
Labour cost/hr (£)	38.15	29.88	36.57	29.35
Total cost/ha (£)	224.80	216.33	212.82	191.71

* does not include contractor labour

The use of a contractor for ploughing, even on a 350 ha, farm can be of benefit. Machine costs using a conventional system with a contractor to plough, were similar to those on a farm with all owned machinery. Total costs were actually lower as the use of a contractor spared some of the farms own labour. If a suitable contractor was available, it would eliminate a considerable peak in labour demand at a critical time.

Simpler mechanisation systems which reduce the amount of energy input into seedbed preparation have scope to reduce machinery costs on larger farms. Substituting a heavy press and Vaderstad-type drill for a power harrow combination reduced costs by about £10 per hectare. The actual saving will depend on the soil type and its need for consolidation.

Minimum cultivation systems also have scope for cost reduction as indicated by the estimates presented here. Both machine and labour cost reductions are possible. The Eco-tillage system costed here included just one pass of the heavy disc unit. This resulted in a substantial saving of more than £30 per hectare in this sample. If a second pass was needed, costs would rise substantially. The cost and labour figures presented here must be treated cautiously as they are estimates only. Research is needed to establish accurate work rates and costs for these systems. While the minimum cultivation system substantially reduces the total quantity of labour required, the need to begin the cultivation process early creates a substantial peak in labour demand at harvest time (Figure 6). Overall the merits of systems like minimum cultivation will depend on the agronomic performance of the system in our conditions. Low machinery costs are only one aspect of the system and good yields are vital to maintain profits.



Note: Different bar segments indicate individual machinery operations

Fig. 6: Labour pattern - 350 ha Eco-tillage

CONCLUSIONS

1. Machinery and labour are closely linked inputs, which have a significant effect on farm viability. All farms must examine their machinery and labour supply strategy.

2. Production costs must be competitive. Smaller units must strive to have similar production costs to large units to remain viable.

3. There are many different ways of achieving economies of scale in machinery use. Systems, which do not increase land area, have scope for efficient production, but they have limited income opportunities.

4. Partnerships and inter-farm contracting are useful development models which should allow lower production costs to be achieved on smaller units.

5. Increasing scale can reduce machinery costs by up to £80 / ha on 50-200 ha units.

6. Labour costs and particularly peaks in labour demand can be significantly reduced by increasing scale.

7. Scale allows alternative mechanisation systems, with potentially lower costs, to be exploited.