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OAK PARK

TEAGASC

2008
Research Report

Members of the Teagasc Authority, December 2008

Director

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Economic control of diseases of cereals crops and evaluation of the efficacy of fungicide products

Dunne, B. ***RMIS No. 5619***

Fungicide efficacy studies using single products, tank mixtures and various co-formulations were carried out on winter wheat, winter barley and spring barley in field experiments at Knockbeg, Co. Carlow, Oak Park Research Centre, Carlow, and Kildalton Agricultural College, Co. Kilkenny. All crop and disease measurements and observations conformed to European Plant Protection Organisation (EPPO) protocols.

Fungicide programmes and fungicide strategy trials on winter wheat, winter barley and spring barley were carried out at the previously mentioned sites and at Duleek, Co. Meath and Arklow, Co. Wicklow. The objective of the strategies trials is to examine the contribution to disease control and yield of various fungicides in both winter wheat and winter and spring barley at each of the key spray application timings. Another objective of these trials was to determine the financial outcome from fungicide programmes in spring barley.

Fungicide Efficacy Trials

Spring Barley

A spring barley fungicide efficacy trial was laid down on the cultivar Wicket at Kildalton Agricultural College, Co. Kilkenny. Thirteen treatments were compared with an untreated control. One -spray and two-spray treatments were applied to the trial plots. The two-spray treatments were applied at growth stage 37 on 9th June and growth stage 61 on 30th June 2008 respectively. The one-spray treatments were applied at the second spray timing. Replication was five-fold. At the time of the first spray there were very low levels of net blotch on the crop. At the time of the second spray there were moderate levels of net blotch on the unsprayed treatments.

In general net blotch levels were moderate at the site. All treatments significantly ($P<0.05$) reduced the percentage net blotch on the flag, second and third leaves at the first time of assessment and percentage necrosis on the flag and second leaves at the second time of assessment. Yield responses to treatment in this experiment were moderate averaging 1.1 t/ha at (range 0.3 t/ha – 1.6 t/ha) over the untreated with the untreated yielding 4.7 t/ha at. Results for are shown in Table 1.

Winter Wheat

A fungicide efficacy trial on winter wheat was laid down at Knockbeg, Co. Carlow on the cultivar Humber. In the trial the efficacy of the treatments to control foliar disease and improve yield was assessed. Foliar disease (caused by *Septoria tritici*) levels at this site were low to moderate early in the season and high later in the season.

In the trial nine treatments were compared with an untreated control. Treatments were applied twice, at growth stage 32 (1st May 2008) and growth stage 41 (26th May 2008). The fungicides used were proprietary named products. Yield responses to treatment were high in this trial and averaged 2.8 t/ha (range 1.0 t/ha – 3.5 t/ha) over the untreated, the untreated plots producing a yield of 7.9 t/ha . The treatment effects for yield and bushel weight (kg/hl) were significantly different ($P< 0.05$) from the unsprayed control. When the controls were excluded from the analyses there were also significant differences for yield between treatments.

All treatments significantly decreased the percentage septoria on the flag, second, third and fourth leaves at three times of assessment. Results are shown in Table 2.

Fungicide Programmes and Strategy Trials

Winter Barley

A fungicide trial comparing ten two-spray treatments, applied at growth stages 32 (21st April 2008) and 65 (19th May 2008), with an unsprayed control was carried out on the winter barley cultivar Spectrum at Oak Park, Co. Carlow. Most plants had Rhynchosporium symptoms on the lower dead leaves and 10% of the plants had infection on the upper leaves at the time of the first spray application. Brown rust became prevalent in June. Yield responses to treatment in this trial were good averaging 1.9 t/ha (range 1.0 t/ha – 2.5 t/ha) over the untreated, the untreated plots producing a yield of 7.3 t/ha. There was a significant effect of treatment (P <0.05) on yield. Disease levels (Rhynchosporium and Brown Rust) were present at moderate levels in this trial. Results in Table 3.

Winter Wheat

Trials comparing spray programmes were carried out at Duleek, Co. Meath and at Arklow, Co. Wicklow. The cultivar used at both sites was Einstein.

Growth Stage 32 (T1) treatment

Five fungicide products were compared at the T1 (growth stage 32) spray timing. T2 (Opus 1.0 l/ha) and T3 (Caramba 1.0 l/ha) were standard treatments. Results are shown in Table 4.
All treatments significantly out-yielded the untreated at both sites. There were also significant differences between treatments for percentage septoria on the second and third leaves.

Growth Stage 39 (T2) treatments

Seven fungicide treatments were compared at the T2 spray timing; T1 (Opus 1.0 l/ha) and T3 (Caramba) applications were the standard treatments.
All treatments were higher yielding and had lower septoria levels than the unsprayed. There were a significant yield and disease differences between treatments. Results for these treatments are shown in Table 5.

Growth Stage 65 (T3) treatments

Nine fungicide treatments were compared at the T3 spray timing; T2 (Opus 1.0 l/ha) and T3 (Caramba 1.0 l/ha) applications were the standard treatments detailed above.
All treatments were higher yielding and had lower septoria levels than the unsprayed. There was no significant yield difference between treatments at the Co. Meath site.
There was a significant disease difference between treatments at both sites. Results for these treatments are shown in Table 6.

Spring Barley

A trial comparing various two-spray fungicide treatments applied at T1 (growth stage 32) and T2 growth stage 65) was carried out on cultivar Sebastian at Oak Park. Sixteen treatments were compared with an unsprayed control. There were moderate levels of powdery mildew present in the crop at the time of the first spray. All treatments were significantly higher yielding than the unsprayed and there were also significant differences between treatments. Results are displayed in Table 7.

Decision Support Systems on Winter Wheat

The performance of four Decision Support Systems (DSS) was compared with a standard three-spray programme .The DSSs on test were: Proplant Expert - Germany, Opticrop – The Netherlands, Plant Protection Online – Denmark and the Theis Septoria Timer also developed in Germany. The cultivar used in the trial, Humber, has a low reading for resistance to *Septoria tritici*. Treatments details are shown in Table X +10.
All treatments were significantly higher yielding than the unsprayed in both cultivars. There was no significant yield difference between the various treatments. Results are shown in Table 8.

Table 1: Fungicide Efficacy Trials. Spring Barley cv. Wicket 2008

		% Net Blotch 17/07/08		R.secalis 17/07/08	% Necrosis 30/07/08		t/ha @ 15% m
Fungicide Products	Rate l/ha	2nd Leaf	3rd Leaf	2nd leaf	Flag Leaf	2nd Leaf	
-------	---						
Venture + Jenton	1.0 + 1.0	6	61	6.4	67	73	6.00
-------	---						
Venture + Proline	1.0 + 0.25	10	62	0.8	54	81	5.81
-------	---						
Venture + Jenton + Bravo	1.0 + 1.0 + 1.0	7	43	4.0	46	67	5.94
Venture + Jenton	1.0 + 1.0						
Venture + Jenton + Bravo	1.0 + 1.0	3	23	0.5	30	43	6.32
-------	---						
Venture + Diamant	0.75 + 0.75	11	67	4.3	67	74	5.61
-------	---						
Venture + Mantra	0.75 + 0.75	7	57	5.3	74	87	5.55
-------	---						
Venture + Lumen	1.0 + 1.0	6	57	9.4	60	68	5.65
-------	---						
Proline + Modem	0.4 + 0.4	8	41	0	65	78	6.10
-------	---						
Mantra + Jenton	0.75 + 1.0	11	61	3.4	78	85	5.74
-------	---						
Capalo + Venture	1.0 +0.75	7	53	3.5	63	76	5.90
-------	---						
Capalo + F 500	1.5 + 0.4	15	55	3.8	78	83	5.77
-------	---						
Opus Team + F 500	1.0 + 0.5	15	83	8.3	88	95	5.03
-------	---						
Fandango	1.0	17	85	0.6	85	97	5.35
Unsprayed		21	80	2.0	100	100	4.69
L.S.D		4	15	n.s.	17	9	0.55

Table 2: Winter Wheat Trial cv. Humber Knockbeg 2008

		% Septoria							
		12/06/08		27/06/08		18/07/08			Yield
Treatment	Rate l/ha	Leaf 3	Leaf 4	Leaf 3	Lea f 4	Flag leaf	Leaf 2	Leaf 3	t/ha @ 15%
Opus Opus	1.0 1.0	12	63	49	97	4	58	100	10.3
EXP 400 EXP 400	1.0 1.0	35	99	98	100	81	10 0	100	8.8
Tocata Venture	2.0 1.5	9	38	32	92	3	46	97	11.0
Proline Proline	0.8 0.8	12	71	68	99	15	72	100	10.2
Proline Prosaro	0.8 1.0	16	87	50	99	7	59	100	11.0
Venture Venture	1.5 1.5	7	58	35	97	2	34	94	10.9
Venture + Jenton Venture + Jenton	1.0 + 1.0 1.0 + 1.0	11	67	30	91	4	43	90	11.1
Gleam Gleam	3.0 3.0	6	41	36	90	2	44	94	10.9
Gleam + Venture Gleam + Venture	1.5 + 1.0 1.5 + 1.0	9	31	17	75	1	21	83	11.3
Venture + Lumen Venture + Lumen	1.0 + 1.0 1.0 + 1.0	7	51	22	94	2	34	92	10.9
Untreated		78	100	100	100	97	10 0	100	7.9
L.S.D.		4	18	16	7	10	10	6	0.9

Table 3: Winter Barley cv. Spectrum Oak Park 2008

		% Rhynchosporium		% Brown Rust		Yield
	G.S.	2nd Leaf	3rd Leaf	2nd Leaf	3rd Leaf	t/ha @ 15%
Bravo + Opus 1.0 + 0.5	32					
Bravo + Opus 1.0 + 0.75	65	3	10	3	2	9.2
Opus 0.5	32					
Opus 0.75	65	6	18	3	1	8.3
Stereo 1.8	32					
Fandango + Bravo 1.0 + 1.0	65	5	16	4	3	9.1
Fandango 1.0	32					
Fandango + Bravo 1.0 + 1.0	65	1	4	2	1	9.2
Proline 0.8	32					
Fandango + Bravo 1.0 + 1.0	65	4	10	2	1	9.2
Venture + Jenton 1.2 + 1.0	32					
Venture + Jenton 1.2 + 1.0	65	1	3	2	1	9.2
Stereo 1.8	32					
Proline + Amistar Opti	65					
0.3 + 1.25		4	13	3	3	9.0
Capalo + Modem 1.6 + 0.5	32					
Capalo + Modem 1.6 + 0.5	65	2	7	1	1	9.4
Fandango 1.0	32					
Fandango 1.0	65	1	5	2	1	9.4
Proline + Modem 0.8 + 0.5	32					
Fandango + Bravo 1.0 + 1.0	65	1	2	1	1	9.8
Untreated		10	18	22	17	7.3
L.S.D.		2	5	8	8	0.8

Table 4: T1 Treatments Winter Wheat 2008 Yield and % Disease

Treatment l/ha	% Septoria 3rd Leaf		Yield t/ha @ 15%	
	Wicklow	Meath	Wicklow	Meath
Venture 1.5	60	37	9.8	10.6
Opus 1.0	87	52	9.8	10.7
Opus + Bravo 1.0 + 1.0	40	49	9.9	10.8
Tocata 2.0	63	51	9.6	11.0
Proline 0.8	78	51	9.6	10.6
Untreated	100	100	7.6	8.5
L.S.D.	15	18	0.4	0.5

Table 5: T2 Treatments Winter Wheat 2008 Yield and % Disease

Treatment l/ha	% Septoria 3rd Leaf		Yield t/ha @ 15%	
	Wicklow	Meath	Wicklow	Meath
Opus 1.0	87	52	9.8	10.7
Prosaro 1.2	75	40	9.7	11.0
Venture 1.5	79	32	9.6	11.1
Opus + Amistar 1.0 + 0.5	81	----	9.3	----
Opus + Bravo 1.0 + 10	43	30	10.1	10.8
Venture + Modem 1.5 + 0.5	----	34	----	11.4
Opus 1.0 *	87	----	9.1	----
Untreated	100	100	7.6	8.5
L.S.D	15	18	0.4	0.5

* No T1 treatment was applied

Table 6: T3 Treatments Winter Wheat 2008. Yield and % Disease

Treatment l/ha	% Septoria 3rd Leaf		Yield t/ha @ 15%	
	Wicklow	Meath	Wicklow	Meath
Caramba 1.0	87	37	9.8	10.6
Caramba + Bravo 1.0 + 1.0	88	65	9.5	10.8
Caramba + Modem 1.2 + 0.4	88	51	9.5	10.4
Caramba + Amistar 1.2 + 0.4	80	61	9.7	10.4
Folicur + Modem 0.8 + 0.4	91	41	9.9	10.7
Prosaro 1.0	82	68	9.7	10.7
Proline + Amistar 0.6 + 0.4	78	57	9.8	10.8
Proline + Modem 0.6 + 0.4	87	56	9.3	10.6
Venture + Jenton 1.0 + 1.0	71	59	10.2	10.9
Untreated	100	100	7.6	8.5
L.S.D	15	18	0.4	0.5

Table 7: Spring Barley cv. Sebastian Oak Park 2008

Treatments	G.S.	% Necrosis Flag Leaf	2nd Leaf	3rd Leaf	Yield t/ha @ 15%
Stereo 1.0	32				
Fandango + Bravo 1.0 + 1.0	65	76	98	100	6.3
Proline 0.4	32				
Fandango + Bravo 1.0 + 1.0	65	41	48	83	7.1
Proline + Corbel 0.4 + 0.3	32				
Fandango + Bravo 1.0 + 1.0	65	39	37	82	7.8
Corbel 1.0	32				
Fandango + Bravo 1.0 + 1.0	65	62	74	97	7.0
Stereo + Corbel 1.0 + 0.3	32				
Fandango + Bravo 1.0 + 1.0	65	36	54	89	6.7
Punch C + Corbel 0.625 + 0.3	32				
Fandango + Bravo 1.0 + 1.0	65	65	75	97	6.3
Fandango 1.0	32				
Fandango + Bravo 1.0 + 1.0	65	37	19	66	7.4
Mantra 1.0	32				
Fandango + Bravo 1.0 + 1.0	65	34	36	68	6.2
Fandango + Corbel + Bravo 1.0 + 0.3 + 1.0	32				
No T2	---	63	46	86	6.5
Stereo + Corbel 1.0 + 0.3	32				
Venture + Bravo 1.0 + 1.0	65	53	59	94	6.6
Stereo + Corbel 1.0 + 0.3	32				
Jenton + Opus + Bravo 0.5 + 0.5 + 1.0	65	51	57	93	6.3
Stereo + Corbel 1.0 + 0.3	32				
Mantra + Bravo 1.0 + 1.0	65	54	58	89	6.4
Stereo + Corbel 1.0 + 0.3	32				
Proline + Bravo 0.6 + 1.0	65	57	69	95	6.6
Stereo + Corbel 1.0 + 0.3	32				
Proline + Amistar Opti 0.6 + 1.25	65	41	55	83	6.5
Stereo + Corbel 1.0 + 0.3	32				
Fandango + Bravo 1.0 + 1.0	65	66	92	100	6.7
Unsprayed		100	100	100	5.2
L.S.D.		21	20	16	1.0

Table 8: DSS Trial Winter Wheat. Disease levels and Yields

Treatment	No. of sprays	% Septoria		Yield	Margin
		Flag Leaf	2^{nd} Leaf	t/ha @ 15%	Over Fungicide Costs (MOFC) €/ha
PC Plantevaern (Danish Online)	2	11	37	10.9	203
Opticrop (Dutch Online)	3	44	50	11.1	192
ProPlant Expert (German Online)	2	16	42	11.3	286
Septoria Timer	2	8	24	11.4	274
Routine 3-spray	3	4	8	11.5	248
Untreated		98	100	8.5	
		12	12	0.7	

Appendix 1: Active ingredients of fungicides used in trials

Fungicide Product	Active ingredients
Acanto	Picoxystrobin 250 g/l
Allegro	Kresoxim-methyl 125 g/l + Epoxiconazole 125 g/l
Amistar	Azoxystrobin 250 g/l
Bravo	Chlorothalonil 500 g/l
Caramba	Metconazole 60 g/l
Corbel	Fenpropimporph 750 g/l
Fandango	Prothioconazole 100 g/l + Fluoxastrobin 100 g/l
Flamenco	Fluquinconazole 100 g/l
Flamenco Plus	Fluquinconazole 54 g/l + Prochloraz 174 g/l
Flexity	Metrafenone 300 g/l
Folicur	Tebuconazole 250 g/l
Impact Excel	Flutriafol 47 g/l + Chlorothalonil 300 g/l
Mantra	Kresoxim-methyl 125 g/l + Epoxiconazole 125 g/l + Fenpropimorph 150 g/l
Menara	Propiconazole 250 g/l + Cyproconazole 160 g/l
Modem	Pyraclostrobin 250 g/l
Opus	Epoxiconazole 125 g/l
Proline	Prothioconazole 250 g/l
Prosaro	Prothioconazole 125 g/l + Tebuconazole 125 g/l
Punch C	Flusilazole 250 g/l + MBC 125 g/l
Sportak	Prochloraz 450 g/l
Stereo	Propiconazole 62.5 g/l + Cyprodinil 250 g/l
Unix	Cyprodinil 750 g/kg
Venture	Epoxiconazole 67 g/l + Boscalid 233 g/l

Investigations of fungicide resistance in cereal pathogens

O'Sullivan, E. ***RMIS No. 5764***

Strobilurin resistance in *Mycosphaerella graminicola*

Studies on the resistance of *Mycosphaerella graminicola* populations in winter wheat crops to strobilurin (QoI) fungicides were continued in 2008. Leaf samples infected with *M. graminicola* were collected from 14 crops selected at random in the main winter wheat-growing regions of the country in March. Monopycnidial isolates of *M. graminicola* were obtained from 20 randomly-selected leaves from each crop and grown on potato dextrose agar (PDA) for four days until conidia were produced. Conidial suspensions of each isolate were added to potato dextrose broth (PDB) in microtitre plate wells in increasing concentrations (0, 0.04, 0.37, 0.12, 1.1, 3.3, 10 and 30 µg ml^{-1}) of technical grades azoxystrobin. Salicylhydroxamic acid (SHAM) (1 µg ml^{-1}) was added to the PDB to inhibit an alternative oxidase respiratory pathway in *M. graminicola*. Growth was assessed as a measure of optical density at 405 nm using a Tecan Saffire II plate reader following 10 days incubation at 18^0C. Growth of sensitive isolates was inhibited at fungicide concentrations greater than 0.12 µg ml^{-1} azoxystrobin while resistant isolates grew well at concentrations up to and including 30 µg ml^{-1} of the fungicide. As in each year since 2003, high levels of strobilurin resistance were again detected in populations of *M. graminicola* in wheat crops. Resistant isolates occurred with frequencies of 100% in 11 crops, 95% in two crops and 64% in one crop. The average was 97% for the 14 crops studied. Following the emergence of resistance to strobilurins in 2002 resistant strains spread rapidly throughout pathogen populations despite a dramatic reduction in the use of strobilurin fungicides. The continuing high levels of resistance indicate that the G143A point mutation encoding strobilurin resistance in *M. graminicola* is genetically stable and carries no fitness penalty.

Sensitivity of *M. graminicola* to triazole fungicides

Populations of *M. graminicola* in 14 winter wheat crops were tested for sensitivity to three triazole fungicides, epoxiconazole, prothioconazole and tebuconazole, the anilide fungicide boscalid and the contact fungicide chlorothalonil. Samples of infected leaves were collected in March to determine the levels of sensitivity prior to the beginning of the fungicide disease control programmes for the season. Isolates of *M. graminicola* (20 per crop) were obtained, tested for growth in technical grade fungicide concentrations (0, 0.04, 0.37, 0.12, 1.1, 3.3, 10 and 30 µg ml^{-1}) and growth assessed as already described. EC50 values (concentrations at which growth was inhibited by 50% relative to untreated controls) for each fungicide were determined for all isolates.

All *M. graminicola* populations remained sensitive to epoxiconazole and prothioconazole, the majority of isolates having EC50 values not greater than 0.37 µg ml^{-1} for both fungicides (Table 1). This shows that there has been no significant shift in the sensitivity of populations of *M. graminicola* to epoxiconazole or prothioconazole despite the more intensive use of triazole fungicides that followed the development of resistance to the strobilurin fungicides in 2003.

Table 1: Sensitivity of *M. graminicola* isolates to fungicides 2008 (% of isolates in each EC50 category)

	EC50 (µg ml^{-1})					
Fungicide	<0.04	0.05-0.12	0.13-0.37	0.38-1.1	1.1-3.3	3.4-10
Epoxiconazole	0	18.3	70.4	11.3	0	0
Prothioconazole	3.3	37.1	51.3	8.3	0	0
Tebuconazole	2.1	27.1	20.4	15.0	22.9	12.5
Boscalid	0	0	13.7	74.3	12.0	0
Chlorothalonil	0	0	71.7	28.2	0	0

Populations of *M. graminicola* comprised isolates that were less sensitive to tebuconazole than to epoxiconazole and prothioconazole with some having EC50 values up to 10 µg ml^{-1} tebuconazole. A shift in sensitivity to tebuconazole was first detected in 2005 but there has been no shifts towards greater insensitivity since then i.e. no isolates have been found with EC50 values greater than 10 µg ml^{-1}.

EC 50 values for boscalid were higher than those recorded for epoxiconazole and prothioconazole. Boscalid is a single-site inhibitor acting as a respiratory inhibitor in the mitochondrial electron transport chain, but at a different complex to that affected by the strobilurins. Fungi have an alternative respiratory pathway that helps to alleviate the effects of boscalid and this probably accounts for the rather high EC50 values in the microtitre plate tests as no inhibitor of this pathway was used. As a single-site inhibitor resistance is likely to develop as a single point mutation resulting in complete resistance, as occurred with the strobilurins. The fact that no significant growth of isolates from any of the crops occurred at the higher rates of boscalid in the present tests indicates sensitive *M. graminicola* populations.

As expected all isolates were sensitive to chlorothalonil. This is a multi-site inhibitor contact fungicide to which *M. graminicola* populations are unlikely to develop resistance. However, it has become a very important component of wheat disease control programmes since the development of resistance to the strobilurin fungicides in *M. graminicola*. The sensitivity tests have established the current levels of sensitivity to chlorothalonil and this may be valuable if there is a disease control problem associated with a programme that includes the fungicide in the future.

Effect of prochloraz in reducing selection of tebuconazole insensitivity in *M. graminicola*

Molecular studies of *M. graminicola* have shown that shifts in sensitivity to triazole fungicides are associated with mutations in the CYP51 gene encoding the target site for these fungicides. Recent studies at Oak Park have shown that mutation I381V in this gene, associated with reduced sensitivity to tebuconazole, occurs in 25% of Irish isolates of *M. graminicola* (see Research Report, 2007). The use of tebuconazole (Folicur) in spray programmes results in rapid selection for these insensitive strains, thus reducing the efficacy of the fungicide. The mutation conferring reduced sensitivity to tebuconazole may increase sensitivity to other DMI fungicides, including prochloraz. It has been suggested that combining prochloraz with affected triazole fungicides in spray programmes may reduce the selection for *M. graminicola* strains insensitive to these fungicides thus enhancing disease control. A trial was carried out in 2008 to study whether prochloraz used in various triazole-based disease control programmes reduced the selection of tebuconazole insensitive strains of *M. graminicola* under field conditions.

The trial was conducted in Knockbeg in plots of winter wheat (cv. Humber). It was laid out in a randomised block with fourfold replication. Plot size was 10 x 2.5m. The fungicide programmes and times of application are shown in Table 1. The main objective of the trial was to test the effects of combining prochloraz with tebuconazole, at different stages in a disease control programme, on the selection of strains of *M. graminicola* with reduced sensitivity to tebuconazole. Each fungicide was applied at the full recommended rate on each occasion irrespective of whether it was applied alone or in combination with another fungicide. Disease severity was assessed on 7 and 21 July. The trial was harvested on 25 August and grain yields determined. Leaves infected with *M. graminicola* were collected from the unsprayed control plots on the day after the first fungicide applications to determine the pre-spray level of sensitivity to tebuconazole and from all plots on 28 July to determine the influences of the spray programmes on sensitivity. Ten monopycnidial isolates of the pathogen from each replicate of each treatment were tested for sensitivity to tebuconazole and epoxiconazole using the micrititre plate method described already.

Table 2: Fungicides treatments applied in tebuconazole insensitivity selection programmes

Treatment	T1 (7 May)	T2 (26 May)	T3 (25 June)
1	tebuconazole	tebuconazole	tebuconazole
2	tebuconazole + prochloraz	tebuconazole + prochloraz	tebuconazole + prochloraz
3	tebuconazole + chlorothalonil	tebuconazole + chlorothalonil	tebuconazole + chlorothalonil
4	epoxiconazole	prothioconazole	tebuconazole
5	epoxiconazole	prothioconazole	tebuconazole + prochloraz
6	epoxiconazole	prothioconazole	tebuconazole + chlorothalonil
7	epoxiconazole	prothioconazole	prothioconazole
8	epoxiconazole + prochloraz	prothioconazole	tebuconazole
9	epoxiconazole	prothioconazole + prochloraz	tebuconazole
10	untreated	untreated	untreated

Table 3: Disease, yield and fungicide sensitivity in *M. graminicola* population in response to fungicide treatments

Treatment	Necrosis (%) Leaf 2		Yield (t/ha)	Mean EC50 (µg ml^{-1})	
	7 July	21 July		tebuconazole	epoxiconazole
1	18.7^{a}	95.8^{a}	11.4^{a}	4.41^{a}	0.21^{a}
2	5.8^{b}	55.0^{b}	11.7^{a}	2.45^{b}	0.18^{a}
3	1.4^{b}	32.0^{b}	11.6^{a}	3.69^{ab}	0.19^{a}
4	7.2^{ab}	41.1^{b}	11.9^{a}	3.51^{ab}	0.24^{a}
5	6.0^{b}	34.8^{b}	12.1^{a}	3.24^{ab}	0.24^{a}
6	5.0^{b}	34.2^{b}	11.9^{a}	4.40^{a}	0.26^{a}
7	6.6^{b}	34.8^{b}	12.3^{a}	2.47^{b}	0.26^{a}
8	3.4^{b}	43.5^{b}	11.4^{a}	3.77^{ab}	0.22^{a}
9	3.7^{b}	45.7^{b}	11.5^{a}	3.92^{ab}	0.24^{a}
10	80.9^{c}	100.0^{a}	8.7^{b}	2.34^{b}	0.19^{a}
Pre-spray				3.02^{ab}	0.22^{a}

abc Means within columns without a superscript in common are significantly different ($p<0.05$), Tukey's Studentized Range Test

The levels of necrosis caused by *M. graminicola* on the second leaves for the two assessment dates are shown in Table 3. All treatments had significantly less disease than the unsprayed control. Of the spray treatments the three Folicur (tebuconazole) sprays (treatment 1) gave the highest incidence of disease which was significantly greater than most of the other treatments on 7 July. On 21 July there was no significant difference between this treatment and the untreated control. All other treatments had significantly lower levels of disease. Adding Sportak (prochloraz) to Folicur (treatment 2) significantly reduced the incidence of disease compared with Folicur alone. All treatments gave significantly greater yields than the untreated control with no significant differences between treatments. The mean EC50 values for the isolates of *M. graminicola* from each treatment are given in Table 3. The lower the EC50 value the more sensitive the *M. graminicola* population. As expected, the highest EC50 value for tebuconazole i.e. the most insensitive population came from the plots that received three sprays of Folicur. Adding prochloraz (Sportak) to Folicur on each occasion (treatment 2) significantly reduced the EC50 value to a level similar to that of the untreated control (treatment 10). The treatment that received triazole fungicides other than Folicur (treatment 7) had a similarly low EC50 value. Adding Sportak to Folicur, either at T1, T2 or T3 caused some reductions in EC50 values but these were not significant.

While combining prochloraz with tebuconazole resulted in better disease control this was probably more a reflection of the higher total fungicide dosage resulting from both products than the reduction in insensitivity to tebuconazole. Combining chlorothalonil with tebuconazole did not reduce selection for insensitivity to the latter, yet it gave better disease control than the addition of prochloraz. In this trial the initial incidence of insensitivity to tebuconazole in the *M. graminicola* population was fairly high as reflected by the pre-spray EC50 value. Under such conditions the reduction in selection of insensitive strain, while significant, is probably not sufficient to make a major contribution to disease control.

Populations of *M. graminicola* remained sensitive to epoxiconazole regardless of the fungicide combinations used. The lowest EC50 values were recorded for the programmes where prochloraz and chlorothalonil had been combined with the triazole at each application and the untreated control.

Fusarium spp causing head blight in wheat.

There are several *Fusarium* spp associated with the head blight complex of wheat. Some of these produce mycotoxins and grain contaminated with high levels of mycotoxins is unsuitable for animal and human consumption. Wheat seed contaminated with high levels of some species e. g. *Microdochium nivale* (*Fusarium nivale*) and *F. graminearum* is unsuitable for sowing since these species cause seedling blight. There has been no recent study of *Fusarium* spp causing head blight of wheat in Ireland. The objective of this study was to identify the *Fusarium* spp associated with head blight and test them for sensitivity to the fungicides used to control them. Heads of wheat showing visual symptoms of blight were collected from 14 winter wheat crops in July in 2007and 2008. The heads were allowed to dry at room temperature and stored until required. *Fusarium* spp were isolated from one grain from each of 20 infected heads from each crop. Hyphal tip cultures of each isolate were maintained for identification and testing.

Microdochium nivale was the dominant species associated with head blight in 2007. In 2008 species other than *M. nivale* predominated. DNA has been extracted from mycelium harvested from all isolates and the species are in the process of being identified using PCR diagnostics. When the species are identified they will be tested for sensitivity to fungicides.

The effect of minimum tillage on the production of spring barley and oilseed rape and an assessment of it's impact on soil characteristics and soil fauna

Forristal, P.D., Kennedy, T., Murphy, K. and Connery, J ***RMIS No. 5615***

This project which commenced in 2007 has the following key objectives

1. To determine the effects of minimum tillage on components of yield, grain yield, grain quality and the profitability of spring barley and winter wheat production.
2. To assess the effects of cultivation system on crop development and seed yield in oilseed rape production systems.
3. To study the stratification of nutrients and soil organic matter in soils subjected to alternative cultivation strategies for more than 6 years.
4. To study the interaction between cultivation system and Nitrogen response in a spring barley crop.
5. To complete the investigations of the effect of cultivation system type on aphids and virus infection of winter cereals.
6. To determine the risk of plant density reduction due to slug damage on min-tilled wheat and to assess the effect of tillage system on aphid numbers in wheat ears.
7. To assess the effects of cultivation system on: **a)** earthworm populations and species composition; and **b)** on the species diversity and abundance of the pest-predator family of ground beetles.

Winter wheat

The experimental design for the wheat trial was changed substantially in 2008 to allow nitrogen response research to be carried out within the cultivation and straw treatment experiments. The large cultivation / straw incorporation plots were retained to ensure the integrity of the previous treatment history was preserved. The Knockbeg site has now been subjected to similar cultivation treatments for 7 years prior to the reported season. The basic experiment is laid down as a randomised block with 4 replications. The cultivation and straw incorporation treatments are:

1. Conventional plough-based system with straw baled and removed.
2. Conventional plough-based system with straw chopped and incorporated.
3. Reduced cultivation (Min-Till) with straw baled and removed.
4. Reduced cultivation with straw chopped and incorporated.

From 2008 within each of these cultivation plots, there are now 10 sub-plots with a 5 x 2 arrangement of applied nitrogen rates and seed rates respectively.

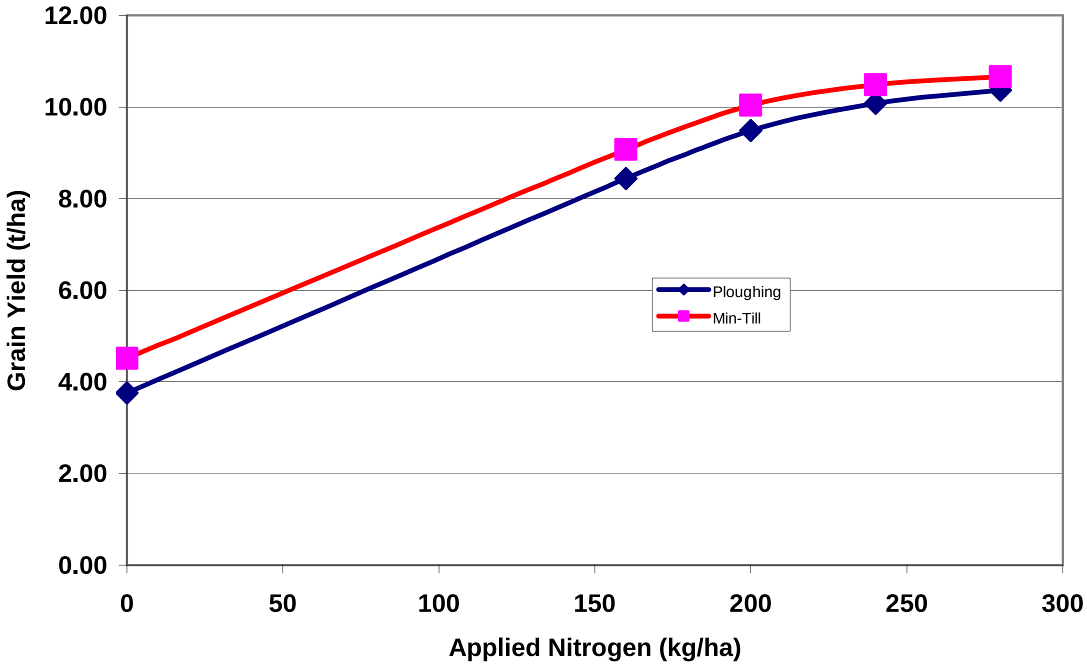
The conventional cultivation (PL) consists of ploughing to 200-250 mm, followed by a single pass of a rotary power harrow to 100-120 mm. Reduced cultivation (MT) consists of one pass in August/September with a 3-metre wide tine cultivator (Horsch), working about 70-80 mm deep, followed immediately by a consolidating run with a roller. This is followed by an interval of about 3 weeks to allow weeds and volunteer cereals to become established, prior to herbicide application. All crops are sown with a cultivator drill (Vaderstad Rapid) modified to produce 2.7m wide plots. Two seed rates are now used to increase the probability of getting similar plant populations with the two establishment systems. The nominal seed rate settings for this season were 200 and 250seeds per m^2. All plots were sown on the 5th October in good conditions. Plant establishment was similar with both cultivation systems (Table 1), aided by the relatively early sowing date. Weeds were effectively controlled with a conventional autumn programme using pendimethalin and isoproturon for grass and broad leaved weeds, followed by a spring application of sulfosulfuron to control sterile brome. A conventional three spray fungicide programme was used for disease control. Five applied N rates: 0, 160, 200, 240 and 280 kg N per hectare were applied in a three split programme. Overall yields were satisfactory in 2008 (yield at 200kg N/ha given in table 1). There was a tendency for the min-till plots to give higher yields, however a preliminary analysis did not show the yield differences caused by cultivation type or straw incorporation to be significant. Grain quality was good with cultivation or straw incorporation having no effect on the parameters measured.

Table 1: Plant counts, grain yield and quality, winter wheat, Knockbeg, 2007-2008

Treatment	Plant count (n)	Yield @ 85% DM (t/ha)	Hectolitre weight (kg/hl)	Screenings < 2 mm (%)
PL - straw	258	9.49	71.1	0.9
PL + straw	257	9.37	70.1	0.8
RC - straw	253	10.04	71.8	0.8
RC+ straw	251	9.80	71.3	0.9
Sig	*ns*	*ns*	*ns*	*Ns*

Preliminary analysis of the response to applied nitrogen indicates a similar response function across both establishment systems but, the tendency for min-till to give higher yields in this season is reflected in a similar shift in response (Fig 1).

Fig.1. Nitrogen response curves for plough and min-till established winter wheat



Winter barley

The performance of winter barley under PL and MT cultivation systems is assessed in a non-replicated observation trial. The systems are evaluated in a 4-hectare field, half of which is ploughed and half established with reduced cultivation. The site is on a free draining gravely sandy loam soil at Oak Park. In this experiment the straw was baled and removed from both treatments. The crop was sown in good soil conditions on 25/09/07. Establishment levels were similar across both treatments. Yields were very good, with the plough-established crop yielding better than that established by min-till. Grain quality parameters were similar with both systems.

Table 2: Plant establishment and grain yield and quality, winter barley, Oak Park (House Field), 2007-2008.

Treatment	Plant establishment (plants/m²)	Yield @ 85% d.m. (t/ha)	Hectolitre weight (kg/ha)
PL	229	9.37	69.2
MT	227	8.61	68.8

There was little difference in observed weed control between the two systems in 2008 with just low levels of sterile brome noted in the min-tilled area of the field.

Spring barley – Oak Park

This non-replicated experiment compares PL and MT cultivation systems for spring barley.

The treatments are as follows.

1. PL - straw incorporation
2. PL + straw incorporation
3. MT - straw incorporation
4. MT + straw incorporation

This was the eight year of the trial and the field had been in continuous spring barley for at least 30 years before this work commenced. The 2-hectare site was divided into two large plots, PL and MT. These areas were further sub-divided into two 0.5-hectare areas on which the straw was baled and removed or chopped and incorporated. Cultivation treatments were similar to the previous year. The crop was sown on March 19th with soil conditions better (lower moisture content) on the plough-established part of the field. Yields were high with the plough based system yielding approximately 0.75t/ha more than the crop established with min-till (Table 3).

Table 3: Grain yield and quality, spring barley, Oak Park (Clonaherk), 2008

Treatment	Yield @ 85% d.m. (t/ha)	Moisture content (%)	Hectolitre weight (kg/hl)	Screenings < 2.2 mm (%)
PL-straw	8.08	17.5	63.0	1.6
PL+straw	8.29	16.9	62.6	1.4
RC- straw	7.31	17.0	62.9	2.1
RC+ straw	7.41	16.3	62.8	2.0

Spring Barley - Knockbeg

A replicated field trial evaluating cultivation systems, applied Nitrogen fertiliser rates, and seed rates was set-up in 2007. The trial site is on a medium to heavy textured soil located at Knockbeg, which presents a greater challenge to the cultivation systems than the more easily worked soils at Oak Park where the previous spring barley observations were located. The main cultivation treatments are:

- **A**. *Conventional establishment:* Ploughing followed by secondary cultivation with a power harrow prior to sowing.
- **B**. *Min-till Autumn:* Stubble cultivation in the autumn followed by sowing in the spring
- **C**. *Min-till Autumn and Spring:* Stubble cultivation in the autumn followed by a second similar cultivation in spring prior to sowing.
- **D**. *Min-till Spring:* Stubble cultivation in the spring only followed by sowing

Within each of these plots, two seed rates (300 and 350 seeds/m^2) and five Nitrogen rates (0, 75, 105, 135, 165 kg/ha) were applied in a 5 x 2 factorial arrangement. For the 2008 harvest season, the treatments that were stubble-cultivated in autumn were tilled on 3rd Sept. All treatments were sprayed with glyphosate on Feb 6th and the over-winter vegetation growth was chopped on February 25th to facilitate cultivation and sowing. Weather conditions prevented spring ploughing and cultivations taking place before April 3rd. All plots were sown on April 7th. Soil conditions on the treatment B plots were less than ideal at sowing. The Nitrogen was applied on two-split basis and all plots received a herbicide programme which included grass weed control and a standard fungicide programme. Measurements included: plant establishment; components of yield and grain yield and quality.

The min-till system where cultivation was only carried out in the autumn had significantly poorer plant establishment rates than all other cultivation treatments (table 4). Soil conditions at sowing contributed to this. The plough based system gave the best establishment.

Table 4: The effect of cultivation system on plant establishment (plant number/m2)

Treatment	300 seeds sown	350 seeds sown
Plough (A)	271	318
Min-Till Autumn (B)	144	192
Min-Till Autumn+ Spring (C)	239	285
Min-Till Spring(D)	227	272
Sig	***	***

The effect of cultivation system and nitrogen rate on crop yield is summarised in Figs 2. The effect of the poorer soil conditions and poorer early crop growth was also evident in the grain yields from the various treatments with the autumn only cultivated min-till treatment having significantly poorer grain yields at all applied Nitrogen levels (Fig 2). Overall yields were poor in 2008 on this site.

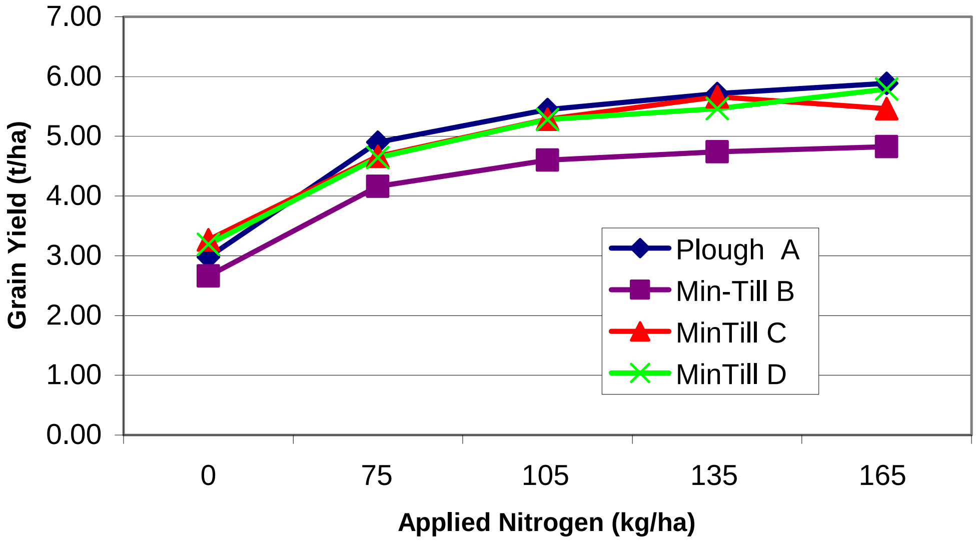


Fig.2. The effect of cultivation system and N rate on spring barley yield (350seed/m2). 2008

Establishment systems for Winter Oilseed Rape

A trial evaluating alternative crop establishment systems was established in the 2006/2007 season and was continued in 2007/2008. The objective was to determine the impact of crop cultivation system, specifically minimum tillage systems on crop yield and components of yield. The cultivation and establishment treatments used were:

A. Plough, press/roll, power harrow/drill, roll

B. Plough, press/roll, vaderstad drill, roll

C. Min-till 75-100mm 1 run, roll, broadcast sow, roll

D. Min-till 75 – 100mm 1 run, roll, vaderstad drill, roll

E. Mintill 75 – 100mm 2 runs, roll, vaderstad drill, roll

F. Min-till 75- 100mm 2 runs, roll, broadcast sow, roll

G. Min-till 150 – 200mm 2 runs, vaderstad drill, roll

H. Broadcast sow, roll (30% extra seed rate)

Two seeding rates: 80 seeds/m^2 and 54 seeds/m^2 were used with each cultivation treatment in a split plot design. (Note: Treatment H had 30% extra seed sown in both of the two nominal seeding rates to compensate for expected poor establishment) The site chosen for the 2008 harvest year was more difficult than used the previous year, being more heavily textured and proving more challenging for cultivation. All plots were sown with the conventional variety, Castille. The plots were sown in good conditions on 7th September 2007. The cultivation plots were 6m wide x 30m long with 5 replications in a randomised block design. Crop establishment varied with the cultivation treatment. The plough established plots had the best plant establishment with the 'autocast' type treatment (treatment H) having significantly poorer establishment than all others, despite higher seeding rates being used (Table 5). The establishment effects were not carried over to crop yield however, where there was no significant differences in yield across all cultivation systems.

Table 5: The effect of cultivation system on winter oilseed rape yields. 2008

Treatment	High Seed rate		Low Seed rate	
	Plant count(n)	Yield (t/ha 9% mc)	Plant count(n)	Yield (t/ha 9% mc)
A	96	4.58	62	4.71
B	70	4.53	42	4.56
C	65	4.88	44	4.79
D	69	4.56	42	4.71
E	72	4.62	45	4.86
F	71	4.89	41	5.09
G	68	4.68	42	4.63
H	32	4.64	20	4.48
Sig	***	NS	***	NS

Invertebrate experiments at Oak Park

Studies on pests, pest transmitted virus disease and on the beneficial field and soil fauna on minimum- and conventional-till winter wheat continued in 2008. Consistent with earlier results, the aphid infestation during autumn 2007 of wheat grown in min-till plots was lower than that for conventional-till plots. As expected, the subsequent aphid transmitted virus infection (BYDV) of wheat was also lower for min-till relative to conventional-till wheat. BYDV infection of wheat grown in plots of either method of cultivation to which straw was incorporated, during cultivation, was lower when compared with wheat plots not receiving straw. BYDV infection was significantly lower (P=0.003) for min-till relative to conventional-till wheat and was significantly lower (P=0.02) for straw treated plots relative to those not receiving straw. The aphid infestation of wheat ears at g.s. 79-80 was low (maximum 2.7 aphids/ear) and no effect on aphid abundance due to either method of cultivation or straw treatment was recorded.

The slug density per ‘refuge trap’ in the period 30 October to 11 December 2007 was lower than that for preceding seasons (range 3.4% to 36.5%). Slugs were significantly (P=0.05) more numerous in min-till plots when compared with conventional-till plots. The incorporation of straw into plots of either method of cultivation resulted in marginally and non-significantly greater slug numbers relative to non-straw plots. The species Deroceras reticulatum comprised in excess of 96% of the recorded slug fauna. In contrast with earlier results, slug damage to wheat plant leaves in November 2007 was lower, but not significantly, for wheat grown in min-till relative to conventional-till plots. Straw treated plots had more slug damaged leaves (P=0.059) than non-straw plots. The examination of wheat seed for evidence of slug feeding on either the germ or endosperm and the examination of seedlings for beneath the soil surface slug damage showed an absence of damage.

Earthworm numbers and biomass, as with earlier results, were greater in min-till relative to conventional-till plots. Straw treated plots had significantly (P=0.01) more worms than non-straw plots while worm biomass was significantly (P=0.005) greater in min-till plots when compared with conventional-till plots. Lumbricus terrestris, a deep burrowing worm species, was significantly more numerous in the min-till plots when compared with conventional-till plots. The species composition comprised Allolobophora chlorotica 16.8%, Aporrectodea caliginosa 2.6%, A. rosea 3.9%, A. longa 0.6%, Lumbricus castaneus 0.4%, L. terrestris 2.8%, and L. rubellus 0.6%. The remainder comprised mostly immatures of which 66.9% were epilobic species and 4.3% tanylobic species. Damaged worms which could not be identified comprised 1.3%.

Ground beetles, Family: Carabidae, were marginally though not significantly more abundant in min-till plots, this trend was more pronounced for larger species such as Pterostichus melanarius.

The plant density for min-till wheat was significantly greater (P=0.003) on 2 November 2007 relative to conventional-till wheat. However, the ear density recorded on 23 July 2008 was significantly greater (P=0.004) for conventional- relative to min-till wheat. Grain yields did not differ either between method of cultivation or between straw and non-straw treated plots.

Cultivation experiments at Knockbeg

Aphid infestation of min-till and conventional-till wheat at Knockbeg during autumn 2007 was extremely low, being only 0.5 aphids/m2. The subsequent recording of aphid transmitted virus disease in wheat plots on 17 June 2008 showed fewer than 0.8% of tillers exhibiting virus symptoms. These results are consistent with those of preceding seasons. The aphid infestation of wheat ears at g.s. 79-80 was negligible. The maximum aphid density of only one aphid per 12.5 wheat ears was recorded for wheat grown on min-till plots in which straw was incorporated during cultivation. Consequently, no effect of either method of cultivation or pre-sowing incorporation of straw on aphid infestation and virus incidence was recorded for the 2007/2008 season.

The number of slugs captured by 'refuge trap' in the period 30 October to 11 December 2007 was the highest recorded, being almost 3-fold that recorded during autumn 2001. Slugs were 16% more numerous in min-till wheat plots when compared with conventional-till wheat plots, however, the difference is not statistically significant. Conventional-till plots in which straw was incorporated during cultivation had non-significantly more slugs when compared with non-straw plots; a similar result was recorded for min-till plots. Deroceras reticulatum was again the dominant slug species but no significant effect on abundance was recorded between the two methods of cultivation or between straw and non-straw treated plots. In contrast the species Arion hortensis was significantly more plentiful in min-till wheat plots compared with those conventionally tilled. Slug damage to wheat leaves, recorded 12 November 2007, showed damage was extensive (range 92.5% to 95.5%). In conventional-till plots 2.1% of seed was damaged by slugs while that for min-till plots was 5.6%. Slug damage did not differ between either method of cultivation or between straw and non-straw treatments.

While earthworm numbers and biomass have increased in min-till plots over the course of this study the 2007/2008 season was the first in which earthworms were significantly (P=0.03) more numerous in min-till wheat plots when compared with conventional-till plots. Conventional-till plots in which straw was incorporated had 21% more worms than those not treated with straw. In the case of straw treated min-till plots worms were 11% more numerous than those without straw. Worm biomass was significantly (P=0.001) greater for min-till plots when compared with conventional-till plots. The species composition was broadly similar to that for the preceding season and comprised Allolobophora chlorotica 19.1%, Aporrectodea caliginosa 0.9%, A. rosea 2.5%, Lumbricus castaneus 0.17%, L. terrestris 0.17%, L. rubellus 0.8%, L. festivus 0.08%, Satchellius mammalis 0.7% and Murchieona minuscule 0.3%. The remainder comprised mostly immatures of which 69% were epilobic species and 3.4% tanylobic species. Damaged worms which could not be identified comprised 2.4%.

Crop production systems: a study of key factors in their performance; long-term effects of rotation and input level; and effective validation and dissemination

Forristal, P.D., Burke, B. ***RMIS No: 5616***

The overall objectives of this project are:

- To determine the interaction between seed rate, applied nitrogen rate and fungicide level in winter wheat.
- To continue studies on the effect of system including input level and rotation type on crop yields and production margin on high and moderate disease pressure sites.
- To compare the effects of 10+ years of monoculture and rotation and input level on soil characteristics, weed flora and soil fauna.

Methods

The trial is primarily carried out at the Knockbeg site adjacent to Carlow with some supporting research carried out at Kildalton. Rotations and input levels are being evaluated at Knockbeg. The development and cropping history of the trial sites was outlined in the 2004 research report. The input strategies evaluated at Knockbeg include:

- ***High:*** Commercial levels of all fertiliser, herbicide, fungicide and other inputs. This is a high-yield, low-risk strategy which is easily managed, but tends towards high production costs.
- ***Low:*** Nitrogen levels reduced to approximately 80% of the 'High' strategy with all other chemical inputs reduced to 50% of the 'High' rate. This is a reduced yield, moderate risk, but easily managed strategy with lower input costs.
- ***Decision-based (DB) High:*** Input levels are in-part determined by a decision making process aimed at optimising response to the input. This is a high-yield, moderate risk strategy requiring greater management levels than the fixed input levels outlined above. (winter wheat and spring barley only)
- ***Decision-based (DB) Low:*** Low levels of inputs which are in-part determined by a decision making process aimed at minimising costs while maintaining adequate yield. This is a reduced yield, high-risk strategy. (winter wheat and spring barley only)

Two rotations: a five course break-crop rotation incorporating a legume and oilseed crop with three cereals; and a three course all-cereal rotation with oats preceding wheat, are grown in comparison with continuous winter wheat and spring barley crops at the Knockbeg site. The basic plot (12.5m x 30m) constitutes an individual crop grown with either high or low levels of inputs with decision-based inputs used on one half of these plots in a split-plot design. Each individual treatment is replicated four times. Decision based strategies are based on a combination of advisory decisions using crop and weather knowledge and computer-based decision support systems (DSS). The DSS systems, which were only used for winter wheat and spring barley (Knockbeg) disease control, were the Danish 'Pro-plant' system for the 'DB-High' strategy on both cereals and the 'DB-Low' strategy on spring barley. The less complex 'Septoria Timer' system was used for the wheat 'DB-Low' approach. As the Danish DSS system recommends extremely low rates of fungicide, these rates were doubled on the DB-high strategies.

Results

Following poor wheat growing conditions in the previous year, 2008 proved more favourable. However wet weather prior to harvest was a particular challenge with some oats and wheat plots badly affected by lodging. It was also a difficult season for spring barley on this heavy site.

W. Wheat and Input levels: When all plots were assessed, wheat yields were similar across all treatments (table 1). However, there was significant lodging across some of the high input treatments making harvesting difficult. If the yield values from these plots were removed, the 'High' and 'DB-High' treatments yielded about 10% extra which would result in the 'Low' input strategy being more profitable as it takes approximately 1.4t of extra yield to pay for the higher input levels. Yields were maintained, when DSS systems were used. As both the DSS systems incurred a lower fungicide spend, this resulted in increased profit levels.

S. Barley and Input levels: Spring barley yields were lower than previous years. The yield difference between 'High' and 'Low' input strategies was, at 23%, greater than most years. As this yield difference is much greater than the 0.7t/ha needed to pay for the higher input levels, the 'High' input strategy was the most economic approach. Interestingly, the DSS system used to determine the fungicide programme did not recommend any fungicide in the 2008 season. While this resulted in a 0.6t/ha yield penalty on the 'High' input strategy, it did not penalise the 'Low' strategy where the limited yield potential resulted in a poor response to fungicide use.

Other crops: In 2008 the winter barley crop showed an uncharacteristically large response to input levels compared to previous years. The winter oats response was affected by crop lodging and subsequent poor weather which resulted in the 'High' input strategy performing poorly.

Rotation effect: The effect of rotation on wheat crop yields was influenced by crop lodging in 2008 as the wheat crop in the break crop rotation was disproportionately affected by lodging (Table 2). In 2008, the winter barley which was grown after an oilseed rape crop yielded almost 20% more than barley grown after a preceding wheat crop.

Table 1: Effect of input strategy on grain yield, Knockbeg 2008

Cereal crop	Input strategy	Yield (t/ha)	Yield excluding lodged plots (t/ha)
Winter wheat	High	10.96	11.55
	DB-High	10.75	11.56
	Low	10.61	10.43
	DB-Low	10.62	10.40
Winter barley	High	8.76	
	DB-High	8.85	
	Low	7.45	
	DB-Low	7.35	
Winter oats	High	6.88	All lodged
	DB-High	6.50	All lodged
	Low	7.39	
	DB-Low	7.38	
Spring barley	High	6.87	
	DB-High	6.29	
	Low	5.29	
	DB-Low	5.16	

Table 3: The effect of rotation on winter wheat and winter barley yields: Knockbeg 2008

Rotation	Wheat Yield (t/ha)	W.Barley Yield (t/ha)
Break Crop	10.24	8.82
Cereal Rotation	11.30	7.38
Monoculture	10.67	

Interaction of seed, nitrogen and fungicide rates in winter wheat

As part of the supporting research for the system trial, the experiment studying the possible interaction of seed rate, fungicide rate and nitrogen rate on wheat yield and disease levels was continued for a third season. Three seed rates (150, 250 and 350 seeds/m2), four nitrogen rates (120, 165, 210 and 255kg N/ha) and three fungicide treatments (0, 50% rate and 100% rate) were studied in a factorial arrangement with 5 replications.

The level of significance for the main effects and interactions on grain yield was assessed. There was no three-way interaction evident. There was a highly significant interaction between nitrogen rate and fungicide level ($P<0.001$) with a lesser response to fungicide use at lower nitrogen rates. All of the main effects had a significant impact on yield.

Effects of biosolids on soil and field fauna

T. Kennedy, N. Artuso and Connery, J. ***RMIS No. 5617***

Laboratory and field investigations on the effects of biosolids on the soil and field invertebrates, including Collembola, Annelida and Coleoptera, continued in 2008. In the laboratory, biosolids from five sources and used at rates equivalent to 0, 2, 5, 10 and 20 t/ha were investigated for effects on the annelid worm *Eisenia fetida* (S.). Comparing biosolids from different sources showed none of the five products caused worm mortality when applied at rates equivalent to 2 and 5 t/ha. At the 10 t/ha rate, two products caused some mortality, one being significantly greater ($P< 0.05$) than the other four. At 20 t/ha, these two products and one other caused significantly greater mortality than the remaining two products. The latter products did not cause worm mortality. Further investigations on the progeny of worms, used in the laboratory study, showed significant differences in the populations of juvenile worms due to different sources and also application rates of biosolids. Laboratory studies on the effects of biosolids on the collembolan *Folsomia candida* are continuing. Processing of invertebrate samples from field trials in 2008 are on-going.

Organic rotation investigation

T. Kennedy and A. Mahon. ***RMIS No. 5248***

Crops were again grown in their preselected sequence in the organic rotation trial in 2008. Winter wheat, sown on 26 October 2007, established satisfactorily and had good yield despite unfavourable weather throughout the season. The grain yields of the four cultivars investigated were: Alchemy 7.1 t/ha, Stratford 7.0 t/ha and 6.7 t/ha each for Seleki and Skalmeji. Ten cultivars of winter triticale were grown and had a mean yield of 4.4 t/ha. Grain sprouting, due to the wet autumn, was prevalent in the triticale cultivars which impacted on yield. Grandval and Benetto were the best yielding cultivars producing 5.5 and 5.4 t/ha, respectively. Of the cultivars grown in previous seasons, Fidelio yielded 4.5 t/ha and Bienvenu 4.3 t/ha. Four cultivars of winter oats were grown in 2008. The grain yields for oats were: Corrib 6.9 t/ha, Evita 6.3 t/ha, Huski 5.9 t/ha and Jalna 5.6 t/ha. Twelve cultivars of spring oats were evaluated on the site by DAFF and had a mean yield of 2.58 t/ha. Orla, Sante and Setanta were again the potato cultivars grown. Potatoes were sprayed with copper sulphate (5 kg/ha) on 6 June, 14 and 29 July and 14 August for the control of blight disease. Tuber yield of potatoes was: Orla 42.2 t/ha, Sante 40.4 t/ha and Setanta 30.7 t/ha. Lupins follow potatoes in the rotation of which Baron, a branching type cultivar, was sown on 23 April 2008. Lupin plots had major weed infestations which made harvesting difficult. Lupins, harvested on 28 October 2008, yielded 1.2 t/ha of grain. The cultivars of spring barley grown were Spotlight and Quench yielding 3.0 and 2.9 t/ha, respectively. DAFF evaluated 13 cultivars on the site and these had a mean grain yield of 2.58 t/ha. The best yielding cultivar in the DAFF trial was Cocktail producing 2.66 t/ha.
A complete review of the organic trial was undertaken during 2008 with widespread consultation with the various stakeholders. A new project on organic arable crop research has been proposed with emphasis on the evaluation of two separate crop rotations.

Evaluation of the agronomic potential of oilseed rape in Ireland

Hackett, R. ***RMIS No.5542***

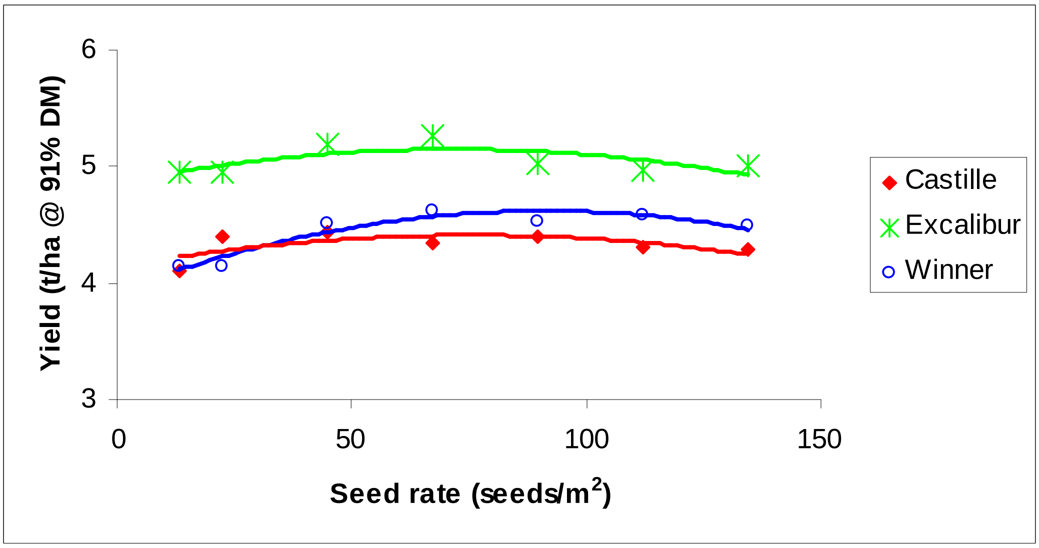


Fig 1. Effect of seed rate and cultivar on yield of oilseed rape at Oak Park in 2008

The effect of seeding rate on yield and quality of oilseed rape was studied in 2007/08 at a site at Oak Park research centre. A two-factor factorial design was used with cultivar and seed rate as factors. Three cultivars were included in the experiment; Winner, a conventional cultivar, Excalibur, a hybrid cultivar, and Castille, a low biomass conventional cultivar. Each cultivar was sown at seven seed rates; 13, 22, 45, 67, 90, 112 and 135 seeds/m^2.There was a significant effect of both cultivar and seedrate (Fig.1). Yield of Excalibur, a hybrid cultivar, was significantly higher than either Winner, a conventional cultivar or Castille, a conventional low biomass cultivar, averaged over seedrates. There was no significant difference between Winner and Castille. There was no significant interaction between cultivar and seedrate. Averaged over varieties the maximum yield was achieved at a seed rate of approximately 82 seeds/m^2. The predicted yield response as seed rate was increased from 13 seeds/m^2 to 82 seeds/m^2 was 0.29 t/ha.

Cultivar differences in terms of oil content, while statistically significant, were small (<1 %). There was a linear decrease in oil content as seedrate increased but the difference between the lowest and highest seedrate was small (0.5%). Due to the relatively small effects of cultivar and seedrate on oil content oil yield, the product of seed yield and oil content, exhibited similar trends to seed yield (Fig 2).

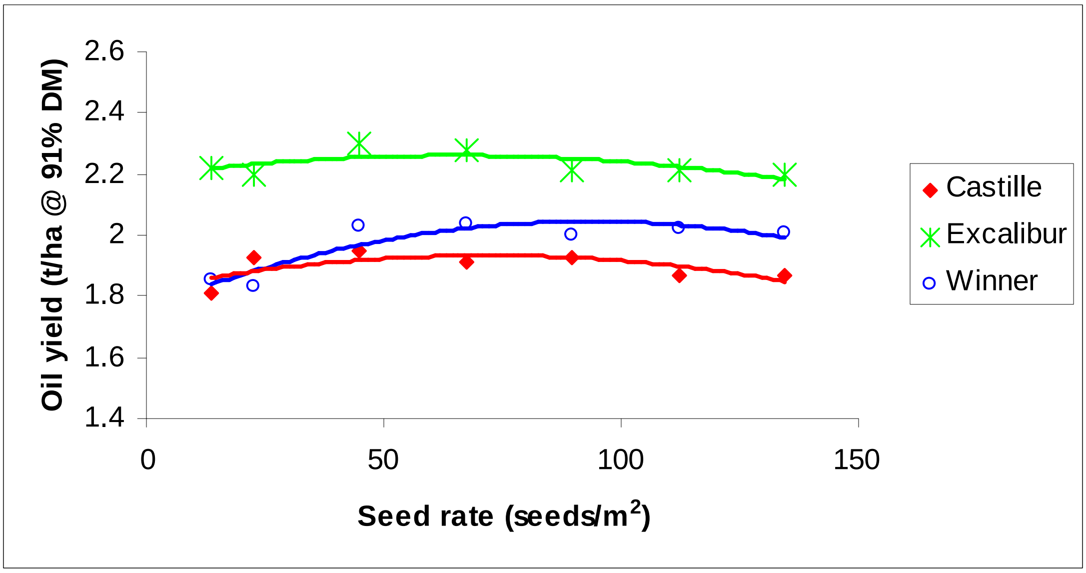


Fig.2. Effect of seed rate and cultivar on oil yield of oilseed rape at Oak Park in 2008

A comparison of 25 cultivars of winter oilseed rape was carried out in 2007/08 at Oak Park (Table 1 and Table 2). Both conventional open pollinated and restored hybrid cultivars were included. A high oleic-low linolenic cultivar, V141OL, was also included.

Yields ranged from 4.3 t/ha to 5.6 t/ha. The mean of the hybrid cultivars (5.1 t/ha) was significantly greater than the mean of the conventional cultivars (4.8 t/ha).

The lowest yielding cultivar was Lorenz which had high levels of light leaf spot during the season. The three highest yielding cultivars were the hybrid cultivars Excalibur and DK Secure and the conventional cultivar Catana. The majority of cultivars yielded between 5 and 6 t/ha. There were significant differences in oil content of the cultivars. Catana had the highest oil content while DK Secure had the lowest oil content. There was no significant difference between the mean oil content of the conventional cultivars and that of the hybrid cultivars. Differences in relative oil yield, the product of seed yield and oil content, generally closely reflected differences in yield.

Table 1: Agronomic characteristics of winter oilseed rape cultivars evaluated at Oak Park in 2008

Variety	Type[a]	Yield (t/ha @ 91% DM)	Relative[b] yield	Oil content (% @ 91% DM)	Relative[b] oil content	Oil yield (t/ha @ 91% DM)
Adriana	C	4.8	97.9	45.6	101	2.2
Castille	C	4.9	98.4	44.5	99	2.2
Catana	C	5.5	111.0	46.2	102	2.5
Cuillin	H	5.3	107.0	45.5	101	2.4
Dimension	H	5.5	112.1	46.1	102	2.6
DK Secure	H	4.5	90.3	43.7	97	1.9
Epure	C	5.1	103.9	45.2	100	2.3
ES Alienor	C	4.3	87.2	44.5	99	1.9
ES Antonio	C	4.3	86.7	45.2	100	1.9
ES Astrid	C	5.0	101.4	43.9	97	2.2
ES Betty	H	5.1	103.9	44.8	99	2.3
Excalibur	H	4.9	99.9	44.7	99	2.2
Flash	H	5.6	113.6	45.7	101	2.6
Grizzly	C	5.1	103.9	45.1	100	2.3
Hammer	H	5.3	107.5	46.1	102	2.4
Hycolor	H	4.9	99.4	44.9	100	2.2
King	C	4.7	95.3	45.6	101	2.1
Lioness	C	4.8	97.4	45.7	101	2.2
MH DG 095	C	5.3	108.0	45.0	100	2.4
NKBravour	C	4.3	86.7	45.0	100	1.9
NK Victory	C	5.1	103.9	45.2	100	2.3
NSL 05/128	C	4.9	98.8	44.9	99	2.2
NSL 07/154	C	5.0	101.9	45.0	100	2.3
V141OL	C	4.5	90.8	45.6	101	2.0
Winner	C	4.6	93.3	44.6	99	2.1
LSD (5%)		0.36	-	0.55	-	0.17

[a] C = conventional H = hybrid

[b] yield or oil content of the variety relative to the average of 25 varieties included in the trial.

Table 2: Agronomic characteristics of winter oilseed rape cultivars evaluated at Oak Park in 2008

Variety	Type[a]	Height (cm)	Relative[b] height	Flowering (days from Mar 30)	Maturity	Lodging score
Adriana	C	162	104	10	8.1	7.6
Castille	C	135	87	8	5.5	8.6
Catana	C	153	98	5	8.3	7.4
Cuillin	H	162	104	0	7.6	8.8
Dimension	H	170	109	5	7.9	8.6
DK Secure	H	142	91	13	5.5	8.8
Epure	C	159	102	21	7.4	6.0
ES Alienor	C	133	85	8	3.6	9.0
ES Antonio	C	149	95	17	7.3	7.6
ES Astrid	C	143	92	17	7.0	8.9
ES Betty	H	171	110	17	7.1	7.9
Excalibur	H	157	101	15	6.0	9.0
Flash	H	179	115	17	7.8	8.4
Grizzly	C	154	99	27	7.4	8.1
Hammer	H	167	107	15	7.6	8.6
Hycolor	H	168	108	15	7.3	8.3
King	C	152	98	1	7.0	8.8
Lioness	C	153	98	15	7.5	8.8
MH DG 095	C	158	101	20	7.8	9.0
NKBravour	C	152	97	15	8.0	8.9
NK Victory	C	160	103	20	6.1	9.0
NSL 05/128	C	152	98	13	7.1	8.5
NSL 07/154	C	149	96	17	7.8	8.2
V141OL	C	160	102	17	6.8	7.6
Winner	C	157	101	13	7.1	7.0
LSD (5%)		7.0	-	-	0.70	0.91

[a] C = conventional H = Hybrid
[b] height of the variety relative to the average of 25 varieties included in the trial

A comparison of the effect of cultivation system and overwinter cover on spring barley grain yield and nitrate concentrations in the soil solution over the winter period

Hackett, R. *RMIS No. 5179*

Studies on the effect of overwinter cover on grain yield of spring barley in a plough-based cultivation system and a reduced tillage system were continued at Oak Park in 2008. Three overwinter covers were compared, no vegetative cover, a mustard cover crop and natural regeneration consisting of volunteer barley and weeds.

The natural regeneration and mustard cover crop were sprayed with glyphosate in late February and chopped in late March. Plough treatments were ploughed in early April before sowing. Reduced cultivation treatments were cultivated in autumn 2007 after harvest of the previous cereal and the only cultivation in spring 2008 was with discs of a Vaderstad drill during the sowing operation. All crops received standard pesticide and fertiliser N inputs with the exception of small areas (2m x 2m) within each plot which received no fertiliser N. These areas were used to determine the effects of the various treatments on growth and N uptake of spring barley in the absence of fertiliser N.

There was no significant effect of overwinter cover on grain yield (Table 1). Grain yield was significantly greater in the plough based system than in the reduced cultivation system but the difference between the two cultivation systems was small (0.3 t/ha). A significant interaction between cultivation system and overwinter cover reflected a significantly reduction in yield where natural regeneration and reduced cultivation were combined compared to all other treatment combinations.

There was a significant effect of both overwinter cover and cultivation method on hectolitre weight; hectolitre weight was significantly higher following ploughing compared to reduced cultivation and was significantly greater in the no cover treatment than in both the natural regeneration and mustard treatments. However differences in hectolitre weights, although statistically significant, were small (0.5 kg/hl).

There were no significant effects of either cultivation method or overwinter cover on 1000 grain weight. There was a significant effect of overwinter cover and cultivation method on grain protein content.

Grain protein was significantly higher in the reduced cultivation treatment than in the plough treatment. Grain protein did not differ significantly between the mustard and natural regeneration treatments. The no cover treatment gave significantly lower protein content than either mustard or natural regeneration treatments. A significant interaction between tillage method and overwinter cover reflected significantly lower grain protein content for the natural regeneration treatment in the reduced cultivation system compared to the plough based system whereas there was no significant difference between either the mustard or no cover treatments between cultivation systems.

Table 1: Effect of cultivation method and overwinter cover type on yield and quality of spring barley (cv. Wicket) at Oak Park in 2008

Cultivation method	Overwinter cover	Yield (t/ha)	Hectolitre weight (kg/hl)	1000 grain wgt (g)	Protein content (%)
Plough based	Natural regeneration	6.0	67.8	53.1	9.0
	Mustard	5.9	67.6	52.3	9.7
	No cover	5.8	67.8	52.1	8.9
Reduced cultivation	Natural regeneration	5.2	67.0	52.3	9.9
	Mustard	5.6	67.2	52.1	9.8
	No cover	5.8	67.8	52.4	9.0
Cultivation method (A)		0.23*	0.34*	ns	0.24*
Overwinter cover (B)		ns	ns	ns	0.29*
A x B		0.40*	ns	ns	0.41*

5% LSD ns = non significant

In the absence of fertiliser N barley grain yield was significantly increased where mustard was the overwinter cover when compared to natural regeneration or bare soil (Table 2). There was no effect of tillage on grain yield or no interaction between over winter cover and tillage method. There was no significant effect of tillage method or overwinter cover on grains per ear or 1000 grain weight. Ear density was significantly increased by the mustard overwinter cover when compared to natural regeneration or bare soil.

Table 2: Effect of cultivation method and overwinter cover type on grain yield and components of grain yield of spring barley (cv. Wicket) in the absence of fertiliser N at Oak Park in 2008.

Cultivation method	Overwinter cover	Ears/m^2	Grains/ear	1000 grain wgt (g)	Grain yield (g DM/m^2)
Plough based	Natural regeneration	351.2	15.8	50.2	236.4
	Mustard	437.0	16.6	51.2	319
	No cover	328.0	14.6	46.7	188.0
Reduced cultivation	Natural regeneration	368.5	16.5	49.4	255.2
	Mustard	463.0	15.8	52.4	326.6
	No cover	352.5	17.1	49.0	247.9
Cultivation method (A)		ns	ns	ns	ns
Overwinter cover (B)		33.6*	ns	2.54*	35.9*
A x B		ns	1.56*	ns	ns

* 5% LSD ns = non significant

An assessment of the potential of cultivar mixtures under conventional and organic management systems in Ireland

P. Fabre and R Hackett *RMIS No. 5375*

Experiments were again carried out to compare grain yield and grain quality of cultivar mixtures of spring barley with grain yield and quality of their component monocultures at four sites in the south-east of Ireland in 2008. Similar experiments were carried out in 2006 and 2007. The objective was to determine if cultivar mixtures are higher yielding than the mean of their component cultivars and/or if the yield of cultivar mixtures is more stable across environments than their component cultivars. Four cultivars (Cocktail, Doyen, Frontier, Tavern), a mixture of the 4 cultivars in equal proportion, four-way mixtures with 85% of one cultivar and 5 % of the other cultivars and four-way mixtures with 45% of two cultivars and 5% of the remaining two cultivars were included in the experiment. Each treatment was repeated at two seeding densities and two nitrogen rates. For analysis the data from all experiments over the three seasons were combined, effectively giving twelve different environments.

The four cultivars had similar grain yields in monoculture at individual sites. Over the range of environments (site x season), there was generally no interaction between cultivars within mixtures for grain yield or for any of the grain quality traits. Reduced density or nitrogen level did not generally affect interactions either. This indicates that there was generally no benefit in mixing cultivars. Therefore, the performances of mixtures could be determined from the performances of their components in monoculture. While there were some positive or negative interactions between cultivars detected in some environments, these interactions were not consistent across environments and were not statistically significant. Overall, this study shows neither positive nor negative effects in terms of yield or quality of mixing cultivars on spring barley crop performances under Irish conditions.

The stability of the four cultivars across environments differed for grain yield and grain quality traits i.e. a cultivar that exhibited grain yield stability did not necessarily exhibit grain quality stability. With the exception of Cocktail, which ranked well for all traits, the other cultivars ranked differently from one trait to another. The stability of mixtures across environments was similar (grain yield and hectolitre weight) or better (thousand grain weight and protein content) than the mean stability of their components in monocultures but was rarely better than the best monoculture. Where cultivars rank differently for each trait, and where this ranking changes across environments, mixtures could be seen as beneficial as they would provide average performances for each of the traits. Therefore, in situation where grain quality is as important as grain yield, mixtures might give greater stability, in terms of grain quality, over a range of environments.

Development of metabolomics based methods to benefit marker assisted breeding in perennial ryegrass

Barth, S., and Byrne, B., ***RMIS No. 5622***

Metabolomics is the study of small molecules that are the end products of gene expression. The project is using metabolomic tools to understand a plants response to various abiotic and biotic stress. Unlike animals, plants do not have the luxury of moving to more favorable environmental conditions when things get tough and depend on internal alterations to help them tolerate stressful conditions. Looking at the metabolome and transcriptome will help us understand what biochemical changes the plant is undergoing when subjected to stress. The target stresses include; drought stress, disease, low phosphorous and low nitrogen.

A number of metabolites and genes regulated by drought have been identified in a plant displaying superior drought tolerance. These may represent targets for improving the ability of perennial ryegrass to survive periods of water shortage, which are predicted as a result of global warming. In particular we have identified many sugars that are accumulated in the more tolerant genotype under water stress and these may act as compatible solutes to protect cells against water loss.

A number of genotypes have also been screened under varying nitrogen (N) applications to identify metabolites under regulation by N. This has been combined with a transcriptomics approach which has identified genes putatively involved in a plants response to limiting N.
A major aim of the project is to map the ryegrass metabolome in an F_2 population consisting of > 380 progeny. Previous work at Oak Park has established a genetic linkage map for this population based primarily on Simple Sequence Repeat (SSR) markers. Leaf tissue samples from two replicated blocks of spaced plants has been collected, and currently both polar and non-polar compounds are being measured by GC-TOF-MS. This will enable us to map metabolites as Quantitative Trait Loci (mQTL) and subsequently compare the position of mQTL to various trait QTL. This may allow the identification of genomic ‘hotspots’ responsible for the control of many metabolites in specific biochemical pathways. Using this top to bottom approach we hope to be able to identify the specific DNA sequences associated with variation for particular traits.

One such trait that has been looked at as part of this project is crown rust resistance. A QTL has been identified on chromosome 2 of perennial ryegrass that represents a region of the genome harbouring gene(s) involved in crown rust resistance. We have mapped an NBS-LRR gene (class of disease resistance genes) within this QTL location, which may point to the existence of a cluster of these genes in this QTL region.

This project is funded by the Irish Department of Agriculture, Fisheries and Food under the Research Stimulus Fund (RSF-06 346).

The organelle genomes of perennial ryegrass: Sequence discovery and genomics for basic and applied agricultural research

Barth, S. ***RMIS No. 5532***

After sequencing and annotation of the *Lolium perenne* chloroplast genome and when the gene sequences were obtained we investigated RNA editing. Editing is a process which alters genetic information at the transcript (mRNA) level. In higher plants, e.g. maize and rice, editing involves that a C-nucleotide on the DNA level is transcribed to a U-nucleotide on mRNA level. Editing can restore conserved amino acid residues. Compared to rice and maize, with 21 and 27 editing sites respectively, we found in *Lolium perenne* 31 editing sites distributed over 18 genes. Five of these editing sites had not been found before in other monocotyledonous species.

Nine new universal chloroplast markers were designed which amplify polymorphic regions within the chloroplast genomes of Poaceae species. All markers detected variation between different Poaceae species. However, one marker was of specific interest being able to distinguish *Lolium perenne* (perennial ryegrass) from *Lolium multiflorum* (annual ryegrass). Another marker was able to distinguish two different haplotypes of *L. perenne* by simple and inexpensive agarose gel electrophoresis. This marker could be of interest if specific traits can be associated with the different haplotypes. An easy screening for plants with those traits could be facilitated by the discovery of this marker. Furthermore, one marker was found that detected via sequencing nearly all the variation that was found by the complete set of new markers among the plant DNA samples (a mixture of Irish and European *L. perenne* ecotypes, *L. perenne* cultivars, different *Lolium* species, different *Festuca* species and other grasses) tested. Most of the variation was due to insertion/deletion events within mononucleotide repeat regions, but also single nucleotide polymorphisms were detected.

Work on the isolation of pure *Lolium perenne* mitochondria DNA continued towards sequencing of the *Lolium* mitochondrial genome.

Generation of mapping tools, construction of suitable plant material and isolation of agronomic traits in Lolium perenne L.

Barth, S. ***RMIS No. 5244***

Biomass yield is under the regulation of multiple genes and several genomic regions are involved. This trait is also influenced by environmental interactions. Therefore the study of this trait relies on Quantitative Trait Loci (QTL) mapping. A genetic map was prepared based on 360 genotypes of an F2 population segregating for biomass yield. Simple Sequence Repeat (SSR) and Amplified Fragment Length Polymorphism (AFLP) markers were mapped on the seven linkage groups (LGs). Three major dry weight and fresh weight biomass QTL were detected consistently under different environments and replications. These were located on LGs 2, 3 and 7.

Current work focuses on the fine mapping of these QTL positions by using additional ryegrass SSR markers and sequence tagged site (STS) markers designed from rice. This approach is possible since a high degree of syntenic relationship was observed between the two species. STS markers flanking the QTL regions on LG 2 and 3 have been developed.

Genomics of the biomass crop Miscanthus: characterizing organelle genomes and assessing nuclear polyploidy variation

Barth, S. ***RMIS No. 5763***

The genus *Miscanthus* belongs to the family Poaceae and has a wide distribution extending from south-eastern Asia, through China, Japan and Polynesia, with few species also in Africa. Attention has focused on this genus because most of its species are capable of great biomass growth in a wide range of climatic conditions and so they could be suitable as alternative energy sources. Very few *Miscanthus* genotypes have been tested for their biomass potential. One species, *Miscanthus* x*giganteus*, has been grown in trials in Ireland for more than 15 years. This is a sterile triploid with a high yield potential and a low invasiveness risk due to its sterility. However to date genomics tools in this species are still rather limited. The overall objectives of the project are to assess cytoplasmic and nuclear gene pools for the genus *Miscanthus* by gathering sequence information for the organelle genomes and chromosome number/ploidy variation data for the nuclear genome.

A collection of 133 different *Miscanthus* genotypes was obtained from different sources and planted in two replications in the field in Oak Park. Herbarium specimens collected from various international herbaria including Kew, Copenhagen, Leiden, and the British Museum are also being screened to measure characteristics in the full range of *Miscanthus* species that have been described in the literature. To date chloroplast microsatellite markers have been developed and applied on the living collection in Oak Park. The ploidy level of these accessions has been determined with flow cytometery, and work on the scoring of morphological characteristics has started in 2008.

The polyploid complex of *Miscanthus* and *Saccharum* has been studied using nuclear ribosomal ITS gene regions combined with analyses using plastid DNA markers (*trnT-L* intergenic spacer, *trnL* intron, *trnL-F* intergenic spacer). All four DNA regions were sequenced for 90 individuals of the *Miscanthus* collection to assess the monophyly of the genus *Miscanthus*. DNA sequences for the *trnL* intron and the *trnL-F* intergenic spacer and the ITS region for 29 *Miscanthus* accessions were selected and aligned with 21 sequences available online from species belonging to both *Miscanthus* and related genera.

Assessing alternative mechanisms to control Septoria tritici

Mullins, E. ***RMIS No. 5536***

The goal of this project is two-fold; investigate the process behind resistance and susceptibility to *Septoria tritici* by identifying key genes that could facilitate the generation of wheat cultivars with improved disease resistance and assess the efficacy of a bacterial-based biocontrol agent in controlling *S. tritici* in the field.

Microarray analysis of a susceptible wheat cultivar following *S. tritici* inoculation identified a total of 64 genes which were up regulated and classified in 10 functional classes with 5 genes related to defence mechanisms. From this list, one gene per functional class (with the exception of transposable element and unknown class) was selected for further validation using a semi quantitative RT PCR assay. From this 5 genes were confirmed to be up-regulated. These genes are:

- Cycloarthenol synthetase (CAS) which is a key enzyme in the sterol pathway.
- NADH-ubiquinone oxidoreductase (NDH2) which is responsible for the oxidation of ubiquinone in the mitochondria.
- Histone H3, whose protein is a main component of chromatin and plays an important point in cell division, DNA methylation, gene silencing and the production of hydrogen peroxide and programmed cell death.
- PR1 which produces the PR1 protein, induced after pathogen infection and is a genetic marker for systemic acquired resistance responses.
- Alanine glyoxylate aminotransferase (Agtx) is a photorespiratory enzyme with multiple substrates in Arabidopsis and so plays an important role in photorespiration in peroxysome in green tissues.

Comparing the expression profiles of a resistant (cv. Flame) and a susceptible (cv. Longbow) cultivar treated with IPO323. In total, 366 genes were up/down-regulated in cv. Flame that were not detected in cv. Longbow. Out of the 366 genes, 156 were classified as fungal responsive (being up regulated in cv. Flame but with no significant difference between cv. Flame and cv. Longbow with respect to their accumulation in water-treated controls). From each functional class (n=15), specific genes were selected for quantitative PCR analysis and within this list 8 specific genes were found to be associated specifically with the resistant phenotype. These include;

- Jasmonic acid-induced protein
- LRR protein
- Br1 associated kinase BAK1
- WRKY70 transcription factor
- Ammonium transporters 2
- Aquaporin PIP1
- Chitinase II cyc7
- Thisulfate transferase

To study the potential of developing a biological control agent as an alternative to control Septoria, several bacteria genotypes were investigated. From the field trials completed for this work, the results clearly indicate an absence of any potential within MKB91 and/or MKB135 to significantly impede STB disease in either of the two winter wheat cvs tested (Einstein and Alchemy) under the conditions examined. Yet, it is promising that *B. megaterium* strain MKB135 did reduce STB to similar levels as the seedling tests under controlled and semi-controlled conditions. *B. megaterium* is often found in rhizospheres and phylloplanes due to its ability to survive and thrive under different nutrient conditions. As these environments tend to be the initial areas screened for biocontrol agents, *B. megaterium* has previously been tested, and has shown the potential to inhibit or suppress a range of plant diseases, occurring on both the roots and aerial parts of the plant. The results suggest that biocontrol of STB by *B. megaterium* strain MKB135 is facilitated by multiple modes of action that can act both locally and systemically. Although an in vitro dual plate culture study did not reveal any evidence that *B. megaterium* strain MKB135 secreted metabolites capable of directly inhibiting M. graminicola, many Bacilli spp. including strains of *B. megaterium*, are capable of producing a range of different enzymes, antibiotics and toxins, many of which can be antagonistic to plant pathogens

Modelling the effects of different crop management regimes on the levels of gene flow from GM herbicide tolerant oilseed rape

Mullins, E. ***RMIS No. 5629***

Funded through the DAFF Research Stimulus Fund

The potential introduction of GM oilseed rape (OSR) into Ireland raises public and sector concern over how the sustainability of a non-GM oilseed rape crop can be preserved in compliance with the EU labelling threshold of 0.9% (i.e. co-existence). Using a computer modelling system (‘GeneSys’), the potential of crop practises to minimise the spread of material (i.e. pollen / seed) from GM herbicide tolerant (GMHT) oilseed rape cultivated fields was investigated.

Utilising a digitised landscape (Bridgetown, Co. Wexford, >607 fields) in excess of 2400ha, for each scenario, simulations were completed at 5%, 15% and 30% rate of adoption and for statistical significance 5 repetitions of each simulation were completed. Specifically, the following scenarios were assessed:

Introducing a delay between ploughing and sowing (1-2 weeks) and the impact of soil moisture levels during this period which effectively examines the impact of increased seed dormancy levels.

Staggering the sowing of GM and non-GM oilseed rape

Increasing weed control with enhanced management use

Introducing field border management regimes (cutting in Nov v. cutting in May v. herbicide use in April)

Grouping GMoilseed cultivation to fields positioned in a cluster to reduce machine travel and potential for seed dispersal. This was implemented with the caveat that there was a 50m separation distance between GM and non-GM fields of oilseed rape.

From the modelling work completed it is clear that farmers will have to adopt several practises for the cultivation of GMHT oilseed rape, based on the completion of the above simulations The clustering of GM fields adjacent to each other presents the best option for future GM oilseed rape coexistence strategies. The inclusion of a 50m buffer zone surrounding each cluster further enhances the potential of achieving effective coexistence and preserving the genetic integrity of neighbouring conventional oilseed rape crops. By ‘grouping’ GMHT fields adjacent to each other, this lessens at a landscape level the potential spread of harvested seed and pollen. By acting as a de-facto GM cooperative, it also provides a degree of security to the farmers, as they can collectively decide which fields are sown with GM seed in any given year based on each other's rotation strategies; thereby minimising the potential for GM admixture in non-GM oilseed rape crops.

Ensuring a more stringent control of oilseed rape volunteers in subsequent cereal crops will reduce the potential for GM admixture in non-GM oilseed crops five fold. This could be achieved through the inclusion of a second herbicide treatment in the spring of the winter cereal crop or increasing the efficacy of the autumn herbicide application to ~97%. The time lag between the harvesting of the GM oilseed rape and the subsequent tillage operations for the winter cereal should be maximised to in excess of 5 weeks; thereby increasing the potential for volunteer seed to germinate. The effect of the described hedgerow management is minimal and did not present a significant impact on the potential for transgene flow across the landscape.

Developing alternative methods to transfer genes into major crop species

Mullins, E. ***RMIS No:5630***

At present, *Agrobacterium tumefaciens* mediated transformation (ATMT) and direct particle bombardment (biolistics) are the two primary systems for the delivery of a transgene into a plant cell line. While both techniques are utilised at Oak Park to generate transgenic material that is employed in the current risk assessment programme of research, they are comprehensively covered by intellectual property rights. This research is focussed on screening novel bacterial strains isolated from the rhizosphere for their ability to deliver genes of interest into both potato and oilseed rape. Following a series of recent experiments, results are being withheld due to the potential patentability of the research conducted in this RMIS.

Separately, four different *S. tuberosum* varieties (Desiree, Maris Peer, Rooster, Kerr's Pink) were treated with three Rhizobia bacteria strains and compared to the standard *A. tumefaciens* as a control. Preliminary results indicate that the provision of antibiotic selection during the shoot inducing stage is crucial in order to get successfully transformed shoots. Tissue treated with the Rhizobia strains as well as the Agrobacterium control show amplification for both transgenes employed, indicating that the transgenes were indeed delivered into the target cells and that the non-Agrobacterium transformation of potato is possible. Further assessment is required to ensure that the individuals from all four treatments have experienced a stable integrationevent.

Enhancing management practises to maintain the sustainability of current potato systems

Mullins, E. ***RMIS No. 5772***

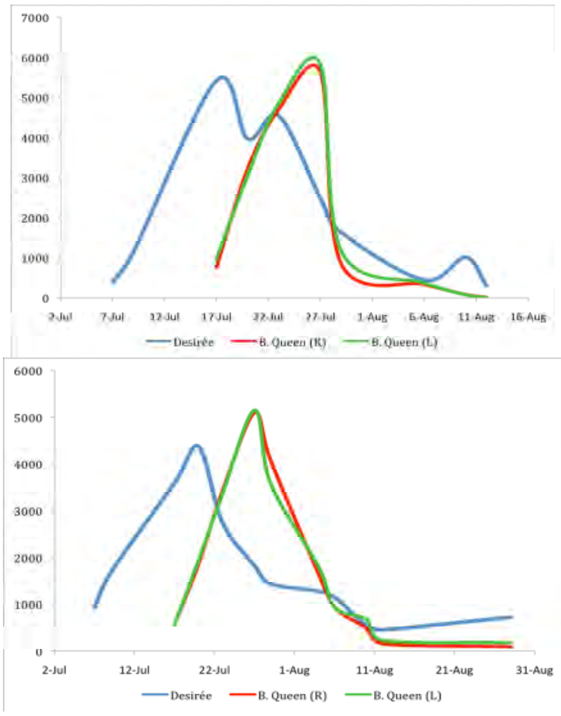
Funded by the DAFF-RSF programme

The four objectives of this project are to:

- Quantify the propensity for pollen-mediated gene flow between potato crops, including the role played by insect pollinators, with the goal of identifying production practises to maintain the genetic integrity of conventional and organic potato crops in co-existence scenarios.
- Evaluate the consequence of pollen and seed-mediated gene flow for co-existence by monitoring volunteer emergence and persistence through rotational practises.
- Determine the frequency of the horizontal transfer of genetic material from potato into associated pathogenic microbes of potato and evaluate its potential environmental and agronomic impact
- Conduct a whole chain analysis to identify 'weak points' in existing production systems that could serve to challenge effective co-existence.

To ascertain the degree of pollen-mediated gene flow between two potato crops, field trials were completed at Oak Park across two independent sites. The male fertile (pollen donor) potato variety Désirée was sown in a 30m x 40m plot with a male-sterile 'pollen trap' variety (var. British Queen) was grown in neighbouring 15m x 40m plots. The sowing of each variety was staggered by two weeks to ensure that flowering across all each site was synchronous (Figure 1).

Fig.1. Flower production at Churchfield (left) and Quarry (right) gene flow sites. The y-axis is showing the total number of flowers on 200 plants. Desirée total number of flowers has been calculated by linear extrapolation.



The frequency of flowering on the pollen receptor sub-plots was recorded at weekly intervals by noting and tagging those inflorescences with at least one fully opened flower. Berry collection from the pollen receptor British Queen drills was conducted at 2-3 day intervals. As British Queen is male sterile, successful gene flow was determined by scoring for the presence of berries on receptor plants. In total 22 berries were collected across both sites (Table 1). The maximum distance recorded for formed berries was 24m. The true potato seed within each berry was extracted and 845 F_1 individuals were sown in the glasshouse. The paternity of each individual is currently being assessed using microsatellite analysis to confirm that each individual was as a result of pollen flow from the pollen donating Désirée variety, sown in the centre of each site. This trial is to be repeated again across two sites in 2009.

Table 1: Total berry and seed harvested. The weight, average diameter, and number of seeds have been counted for 50 Desirée berries and the total of B. Queen berries

Site	Potato variety	Nº berries collected	Average diameter (cm)	Weight (g)	Total seeds	Average Nº seeds/berry
Quarry	Desirée	200	3.451	4.53	8257	146.5
	B. Queen (windward)	5	1.738	1.909	273	34.125
	B. Queen (leeward)	8	1.720	1.861	210	35
Churchfield	Desirée	200	3.692	4.372	7303	122.44
	B. Queen (windward)	3	1.749	2.051	107	35.67
	B. Queen (leeward)	6	1.698	2.224	255	42.5

To identify ‘weak points’ in existing production systems that could challenge co-existence, a detailed review was conducted of a 200ha potato farm in Co. Louth that produces both ware and seed potatoes. Key challenge points in the traditional production system include; seed segregation and labelling pre-sowing, product labelling and segregation during post-harvest processing, volunteer management through the rotation and ensuring adequate separation distances between GM and non-GM crops with comparable levels of fertility.

High value products and ethanol from wheat straw and bran: enhancing our understanding and capacity for fungal bioconversion

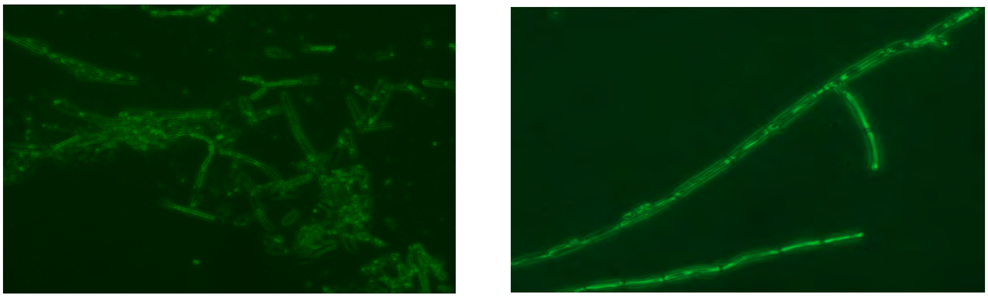
Mullins, E. **_RMIS No. 5773_**

Funded by the DAFF-RSF programme

This study will enhance the potential of using *Fusarium oxysporum* to produce bioethanol and other added-value products (e.g. ferulic acid) from farm-based renewable materials. Commercial production of alcohol from wheat renders the majority of hemicellulose unutilized, reducing the efficiency and cost-effectiveness of the process. *F. oxysporum* is a good candidate for the direct and efficient conversion of relatively low-value lignocellulosic materials to ethanol. Although fermentation performance by *F. oxysporum* is somewhat lower than that of other fermenting microorganisms, its ability for simultaneous lignocellulose-residue saccharification and fermentation is considered as a significant advantage. Employing gene modification via *Agrobacterium*-mediated transformation the goal is to identify enzyme-encoding genes of interest and gene promoters of interest to the biofuel industry (i.e. that drive high gene expression during lignocellulose conversion).

The first task is to establish an *Agrobacterium*-mediated transformation process for *F. oxysporum*. Employing several strains of *F. oxysporum*, their resistance to the screening antibiotic, hygromycin, was first assessed. The levels of endogenous hygromycin resistance in the selected *F. oxysporum* isolates varied from ~20ug/ml up to 50ug/ml. As such the use of a generic 60ug/ml hygromycin was adopted for the initial transformation experiments. These were completed with the pBHt1 T-DNA vector, which contains the hygromycin resistance gene (hph) and the green fluorescent protein (gfp) marker gene, to screen for and visualise transformants in culture respectively.
Each transformation experiment involved the co-cultivation of *F. oxysporum* conidia (1×10^6 conidia per ml) with *A. tumefaciens* cells containing the transformation vector (pBHt1). After plating this suspension on a nylon membrane and incubating for 48 hours at 25^{o}C, the filter was transferred to minimal media supplemented with hygromycin and timentin (to kill off *Agrobacterium*). Individual transformants (Figure 1) were visualized under a binocular microscope and transferred into 24-well and incubated until conidiogenesis.

Fig.1. GFP fluorescing isolates of *F. oxysporum*



Conidia of individual GFP-expressing transformants was suspended with sterile water and plated out to generate monoconidial cultures, from which a single germinating conidium from each transformant was used to generate a permanent culture stock for the GM *F. oxysporum* library. Each transformed *F. oxysporum* strain is currently being tested for its ability to produce ethanol compared to the unmodified parent *F. oxysporum* strain.

Development of a framework for marker assisted selection in the breeding of the novel non-food crop *Adonis palaestina*

Milbourne D., Bigio, G. ***RMIS No. 5544***

Adonis palaestina, a plant originating from the middle-east, is a potential source of the red pigment astaxanthin, which has uses both as a high value antioxidant nutraceutical and as a feed additive for farmed salmonid fish species. The species is not established as a crop and a programme of domestication is underway at University College Cork to obtain lines that can be cultivated to exploit the production of the secondary metabolite. As part of that domestication process, this project involves undertaking a basic level of genetic characterisation of the available breeding germplasm to provide information that will underpin future efforts to domesticate and improve the species using both conventional and biotechnology-based approaches such as marker assisted selection (MAS).

The process of domesticating a species for agricultural use can frequently result in a reduction in genetic diversity of the resulting adapted material. In order to monitor this, we have carried out a genetic diversity analysis of available *Adonis* germplasm using AFLP markers. The analysis suggests that the currently available breeding germplasm at UCC has a high level of nuclear genetic diversity. Creation of this benchmark will allow any future erosion of nuclear diversity to be monitored and ameliorated. In addition, the data suggest that the creation of genetic linkage maps in order to map key traits as a basis for MAS-based approaches to improvement of the species will not be hindered by a lack of nuclear DNA polymorphism.
Two groups of lines, exhibiting distinctly different flowering morphologies are available at UCC, both of which have been described as *Adonis palaestina*, the first is a small flowered type with a double row of petals, the second a large flowered type with a single row of petals. An apparent barrier to sexual hybridisation of the two forms exists, and this has previously been assumed to be due to a ploidy difference between the two sets of lines (the large flowered lines being assumed to be tetraploid variants of the diploid small flowered lines).

Using a combination of flow cytometry, to compare the nuclear genome sizes of the lines, and DNA sequencing of the ITS region of the 16s ribosomal rNA subunit, we have found that it is unlikely that this crossing barrier results from a difference in ploidy, and in fact, that the two flower type groups probably represent different species or subspecies, a key piece of information in the domestication process for this plant.

This project is funded by the Irish Department of Agriculture, Fisheries and Food under the Research Stimulus Fund, and is being carried out in collaboration with Prof. Peter Jones at UCC.

Developing a knowledge base for the biotechnology-driven exploitation of self incompatibility in white clover breeding

Milbourne, D., Barth, S., Casey, N. ***RMIS No.5761***

Self incompatibility, the inability of a plant to be fertilised by its own pollen, is a major characteristic determining the breeding strategy for many agriculturally important plant species. The major forage legume used in Irish pasture, white clover (Trifolium repens L.) exhibits self-incompatibility. Self-incompatibility (SI) is known from approximately 60 percent of all angiosperm species, and the mechanism has been investigated in some families, e.g. Solanaceae, Rosaceae, Plantaginaceae, Papaveraceae and Brassicaceae. In Papaveraceae, Solanaceae and Rosaceae, and in Antirrhinum (Plantaginaceae), the specificity of the SI reaction has been shown to be determined by the products of a single multi-gene region in which the genes are tightly linked, the self-incompatibility (S) locus. The basis of this project is to use a combination of classical and molecular genetics-based approaches to characterise the S-locus in white clover, with the ultimate goal of identifying the genes involved in this process in white clover.

Members of the Solanaceae, Rosaceae, and Plantaginaceae share closely related ribonucleases (S-RNases) as female receptors in SI. In terms of evolutionary relationships and what is known of the SI mechanism in T. repens, it is very likely that the female receptor is related to those in Rosaceae, Solanaceae, and Plantaginaceae. On this basis, in the molecular genetics-based approach, we have been using a degenerate polymerase chain reaction (PCR)-based approach to amplify S-like RNAses from white clover using primer sets based on the aforementioned species. Several such sequences have been amplified from clover to date, although none of them exhibit all of the expected structural features of S-RNAses from other species. In the classical genetics approach, results of cross-pollination experiments in a white clover mapping population (for which a genetic map was previously constructed in RMIS5178) show that the SI reaction in T. repens can also be explained as the effect of one locus. It is envisaged that extension of the cross pollination experiment in the coming year will allow the genetic location of the clover SI locus to be determined. Good candidates genes for the female receptor component of the SI mechanism identified using the molecular genetics approach described above will also be mapped in the population to test whether they are associated with the SI interaction.

Sequencing potato chromosome IV

Milbourne, D., Destefanis M., ***RMIS No. 5545***

Teagasc is participating in the international initiative to sequence the genome of potato as part of the Potato Genome Sequencing Consortium (PGSC). The initiative is currently structured on a chromosome basis, and Oak Park researchers are focussing on sequencing potato chromosome IV (potato has a basic chromosome number of 12) in collaboration with partners in the UK. The sequencing initiative is based on the availability of genetic and bacterial artificial chromosome (BAC)-based physical maps of a diploid potato genotype called RH, which were developed in two previous EU-funded projects. Using these resources (hosted by the University of Wageningen in the Netherlands), researchers at Oak Park, and collaborators at the University of Dundee and the Scottish Crop Research Institute have released the sequences of 39 potato BACs into GenBank, the public nucleotide sequence database, in 2008. The accession numbers of these BACs are AC233602 - AC233640. Teagasc will continue to contribute to the PGSC initiative with further BAC and whole genome shotgun sequencing activities in the coming year.

The potato cyst nematode Globodera pallida Pa2/3 is one of the most relevant soil-borne pests of potato in Europe. A quantitative trait locus, called Gpa4, that confers resistance to G. pallida has been identified on the short arm of potato chromosome IV, in a region which harbours a resistance hotspot conferring resistance to this nematode and to unrelated pathogens. In addition to sequencing chromosome IV, a further objective of this study is the identification of the genes involved in conferring the resistance phenotype at the Gpa4 locus by producing a high quality annotated gene sequence map of the region. A number of BAC clones from this region were identified using markers genetically linked to Gpa4. The BACs were sequenced and assembled, in part by exploiting the synteny between the potato and tomato genomes. Putative genes expressed in the BAC sequences were identified using an ab initio gene prediction package, and further analysis revealed that one of the BACs contains 2 R gene candidates, belonging to the NBS-LRR sub-class of resistance genes. Their sequences revealed a high degree of similarity to Rpi-Blb3, a late blight resistance gene that clusters in the same resistance hotspot on chromosome IV.

Breeding and evaluation of improved potato varieties for the domestic and seed export markets

D. Griffin, D. Milbourne J. Dillon C. Kennedy F. Hutton J. Deegan and L.J. Dowley
RMIS No. 5612

Objectives

The objectives for the breeding program in 2008 were to produce varieties with the following attributes

- Early maturity and high yield potential
- Excellent processing and quality traits
- Smooth bright skin finish
- Resistance to late blight and potato cyst eelworm

Seedling evaluation in Ireland

The size of the program remained similar to previous years. The number of seedlings tested at each generation in Ireland and the trial sites used are outlined below.

Table 1: Number of seedlings under field evaluation in Ireland 2008

Year of generation	Type of trial and location	No. seedlings under evaluation
Year 3	Singles in Wicklow Mountains	69,192
Year 4	Ten tuber lots in Wicklow Mountains	2,643
Year 5	Replicated plots (3 replicates each of 30 plants) [Carlow]	184
Year 6	Replicated trials	
	Maincrop: Carlow	38
	Early: Wexford	8
Years 7-11	Replicated trials: Maincrop: 2-4 sites (Carlow, Wicklow, Louth and Meath)	30
	Early: Wexford	12
National List Trials (Dept. of Agriculture, and Food)	Maincrop: 3 sites (Cork, Meath, and Kildare)	3

Table 2: Number of seedlings under field evaluation abroad 2008

Country	Partner	No of trials	Type of trial	Location	No of seedlings
United Kingdom	NIAB, Cambridge	1	Clonal	Lincolnshire	28
Canary Islands	PEP Ltd	1	Clonal	Moya, Las Palmas	29
Morocco	Dynagri	2	Clonal	Soalem and Ziane	28 62
Spain	PEP Ltd	1	Clonal	Seville	29
	PEP Ltd	1	Clonal	Valladolid	63
United Kingdom	NIAB, Cambridge	1	Breeders observation plots	Cambridge	5

Trial analysis
The northern European (Ireland and UK) and Mediterranean trials were treated as distinct experiments for analysis purposes. Although different seedlings were included in each experiment a core group of seedlings that were either in national list trials or under consideration for entry to NL trials were included at all sites so a balanced data set could be achieved for the purposes of cross trials analysis.

For the Mediterranean trials these seedlings were

T3302/3, T2208a31, T3537/2, T3588/17, T3637/2, T3747/10, T3747/13, T2345/1, T2516/15, T3634/37, T3653/9, T2592b22, T3717/28, T3854/3, T3854/20, T3868/21, T3954/14, T3954/51, T3961/64, T3983/1, T3999/11, T4062/22.

For Irish and UK trials these were

T3302/3, T2208a31, T3537/2, T3588/17, T3637/2, T3747/13, T2345/1, T2516/15, T3634/37, T3653/9, T2592b22, T3717/28, T3854/3, T3854/20, T3868/21, T3954/14, T3954/51, T3961/64, T3983/1, T3999/11, T4062/22

Irish and UK yield trial results:
Two trials were analysed at sites in Carlow and Lincolnshire in the UK. Overall Score (breeders impression), marketable yield and fry (crisp) colour results for each of the seedlings are shown in Table 3.

Table 3: Overall score, crisp colour and marketable yield of advanced seedlings at two trial sites Carlow and Lincolnshire UK in 2008

	Oak Park Carlow			NIAB Lincolnshire		
Seedling	Overall score	Crisp Colour	Marketable Yield t/ha	Overall score	Crisp Colour	Marketable Yield t/ha
Cara	7	4	59.07	6.7	5	75.48
Desiree	7	5.3	54.53	5.3	6.5	67.03
Rooster	6.8	5.7	62.97			
Maris Piper	6.7	5.7	57.3	5.7	7	52.99
Orla	7.2	4.7	71.57	6	5	66
Lady Claire	6.3	8	37.53			
Lady Rosetta				6.3	8.5	57.47
T 3302/3	7	6.3	62.6	7.2	7.5	64.03
T 2208a31	6.3	5	63.07	5.5	5.5	50.94
T 3537/2	7.2	4.7	66.53	7	5	78.31
T3588/17	6.7	4.7	59.4	5.8	4.5	59.71
T 3637/2	6.5	3.7	57.7	5.7	4.5	65.66
T3747/13	7.7	4.7	67.77	7	5	64.97
T2345/1	6.7	4	58.63	7	6.5	71.26
T2516/15	6.3	5.3	51.13	6.7	6.5	62.25
T3634/37	6.8	3.7	70.13	6.7	4	66.09
T3653/9	6.2	3	49.5	6.3	5.5	72.04
T2592b22	6.7	5	73.63	6.3	7	69.47
T3717/28	6.7	2.7	72.63	5.7	5	77.99
T3854/3	6.2	5	53.1	5.5	6	57.41
T3854/20	6.5	5.3	49.3	5.3	7.3	46.9
T3868/21	7	5.7	55.5	6	7	63.27
T3954/14	6	3	51.43	6.2	5	52.46
T3954/51	7.3	3	72.8	6.3	5	63.88
T3961/64	7.5	4	74	7	5.5	71.49
T3983/1	6.3	4.7	61.53	6.3	5	70.03
T3999/11	7	4.3	68.1	5.3	5	74.05
T4062/22	6.3	4.3	62.47	6.2	6	61.25
LSD	0.65	0.83	9.22	0.63	1.18	10.93

The best performing seedlings in this trial series with regard to overall breeders impression were T3302/3, T3537/2, T3747/13 and T3868/21. T3961/64 received the highest overall score at Carlow but did not perform as well in Lincolnshire, it was the highest yielding seedling across the two sites. Cara was the highest yielding control variety in Lincolnshire while Orla was the highest yielding in Carlow. Of the seedlings T 3302/3 had consistently the best fry colour, but was slightly inferior to the controls Lady Rosetta and Lady Claire. This seedling is showing considerable promise as a crisping variety as it consistently out yields the previously mentioned control varieties. T3868/21 and T2592b22 had good crisp colours and show some promise for French fry production.

Mediterranean trial results:

Seedling evaluation also took place at five sites in the Mediterranean/North African region in conjunction with Irish Potato marketing and foreign partners.

The yield data was subjected to analysis across sites using the additive main effects and multiplicative interaction (AMMI) model for a 2-way genotype by environment balanced set of data as outlined by Zobel, Wright, and Gauch (1988). The AMMI ANOVA indicated highly significant differences ($P<.001$) for genotypes, environments and genotype x environment interaction.

In the Ammi model principal component analysis is conducted on the covariance matrix. In this case the model calculated four principal component axes of which only the first two were significant. A plot of adjusted average yield of the sites and genotypes across the five sites against the first PCA axes scores are shown in Fig 2. The X axis represents the main effects of yield for genotypes and environment while multiplicative interactions are represented by the Y axis. In interpreting this graph, if a variety is very close to zero on the Y axis then it has small interaction effects. When a genotype and an environment have the same sign on the PCA axis the interaction is positive; if different the interaction is negative.

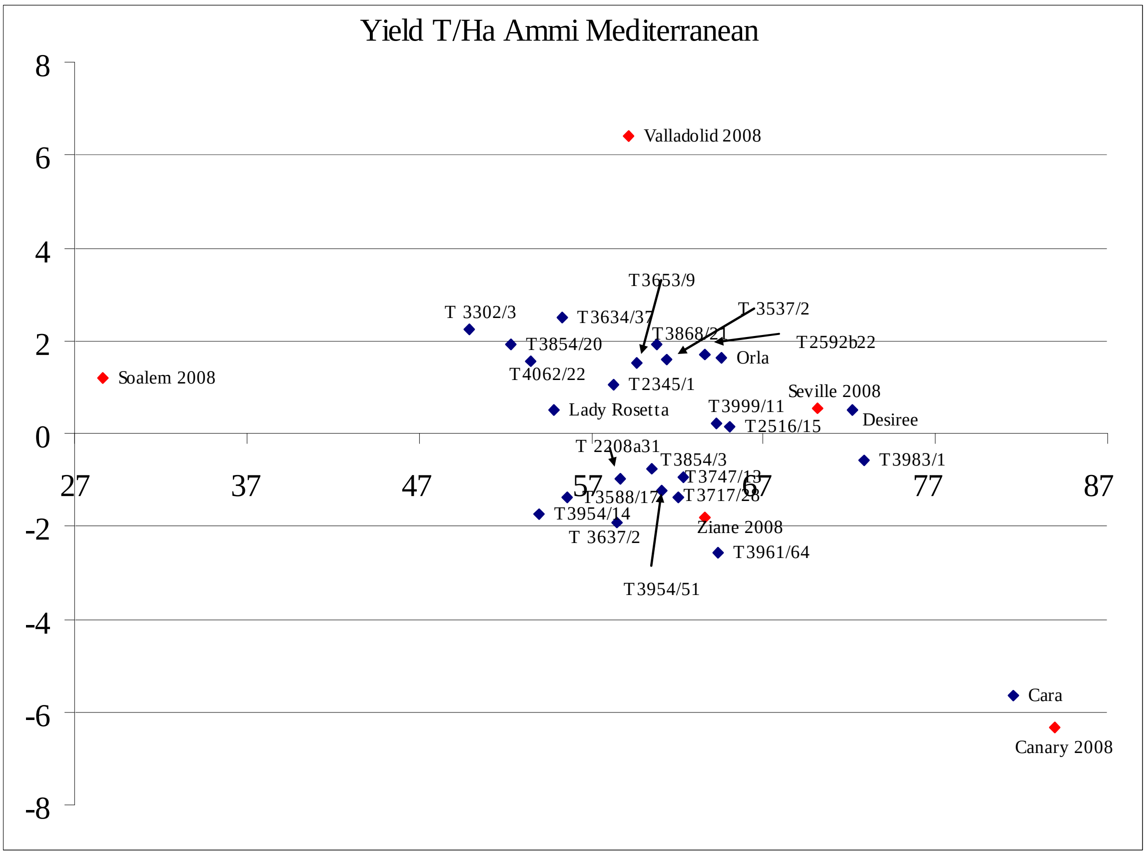


Fig.1. Bi-plot with X axis plotting trial and genotype mean yields (t/ha) and Y axis plotting PCA 1 scores. Trial means are shown in red and genotype means in blue. Selected controls and advanced seedlings are labelled.

The highest yielding seedlings in this trial series were Cara, T3983/1 and Desiree. Cara however was extremely variable across the sites showing a very large positive interaction with the Canaries site. This effect is noticed almost every year. Cara is the most extensively cultivated variety in the Canary Islands and is well adapted to local conditions there. Cara showed a large negative interaction with the three lower yielding sites Seville, Valladolid and Ziane. T3302/3 was the lowest yielding seedling across the trial series; however this is due to the varieties extremely high dry matter which makes it suitable for processing.

National List and DUS Trials

Seedling T3747/13 completed national list trials in 2008 and along with T3302/3 will be added to the Irish national list in 2009. Seedlings T3537/2 and T2516/15 were re-entered for NL2 trials in 2008 after performing well in NL1 trials 2008.
Two new seedlings were proposed for NL1 trials in 2009. These were T3983/1, and T3868/21. These advanced seedlings are described below.

T3302/3 is an early maincrop deep red variety. Flesh colour is light yellow. The variety is low to moderate yielding but has extremely high dry matter and good fry colours. The variety should be suitable for the production of crisps and was consistently higher yielding than the control Lady Claire which is the commercial standard. The variety gives similar fry colours.

T3747/13 is a high yielding early maincrop variety. Skin finish is excellent and the variety has a very deep red skin with white flesh. The seedling is suitable for pre-packing for fresh consumption.

T2516/15 is a maincrop variety with white skin. Skin finish is excellent and tuber shape is long oval. The variety has moderate tuber size but has high dry matter and excellent eating quality. It may be suitable for French fry production.

T3537/2 is a deep red skinned round variety with maincrop maturity. Skin finish is excellent. The variety has moderate dry mater levels and a deep yellow flesh. Yield is extremely high and the variety is highly resistant to a range of diseases including late blight.

T3983/1 is a deep red skinned white fleshed early maincrop variety. It is very high yielding and performed well in all southern European sites. Tuber shape and uniformity are excellent. Skin finish may be a little dull. The seedling is particularly suited to North African markets

T3868/21 is a yellow skinned yellow fleshed early maincrop variety. It has potential for both the home war and export market and is suitable for French fry production. It performed well in both southern and northern European trials.

Grants of Plant Breeders rights

Varieties Electra and Romeo both received grants of European plant breeders' rights in 2008.

The production of virus tested seed stocks of new potato seedlings

The objective of this programme is to ensure that an adequate quantity of virus tested seed is available for multiplication under the seed certification scheme when a new potato variety is recommended for release. It is also designed to produce high quality seed for the commercial evaluation of seedlings at home and abroad.

The production of virus-tested stocks of new potato seedlings was continued at the isolation centres in Wicklow and Myshall during 2008. This covered an area of approximately 6.5 ha and was made up of plots varying in size from single-plant plots to 1,500-plant plots. Virus testing and seed distribution was similar to previous years.

During the winter, samples of all clones are tested for virus infection using the ELISA technique. All infected clones were discarded. All advanced clones are also tested for the presence of potato spindle tuber viroid (PSTV) using the nucleic spot hybridisation test and for ring-rot and brown rot using the immuno-flourescent technique.

During the growing season a total of 75,374 plants were sampled from 3,519 clones representing 3,221 seedlings. This material was subjected to 36,480 serological tests using the ELISA technique. Visual examinations were also carried out at weekly intervals. A total of 1,006 clones were infected with PVY, 30 clones infected with PVS, 359 clones infected with PVA, 19 clones infected with PLRV and 46 clones infected with PVX. This represents a significant increase in infection with the aphid transmitted virus PVY compared with previous years despite a more remote isolation centre and more stringent entry standards. All infected clones were discarded from the propagation programme.

The produce of selected seedlings was sent for trial to 8 countries while the remainder were used for further propagation, disease resistance screening and demonstration.

Meristem-tip culture and micro-propagation

During 2008 meristem-tip cultures of 2 advanced seedlings (T2516/15 + T3961/64) were handed over to the Department of Agriculture and Food for micro-propagation under the Irish Seed Potato Certification Scheme. Following confirmation of the health status, this material is also forwarded to Scotland for multiplication under the Scottish Seed Certification Scheme.

Marker Aided selection

One of the major goals of the potato breeding program is to produce varieties resistant to potato cyst nematode and particularly to the *Globodera pallida* strain. For the last three years markers have been used at the year 4 stage of the program to identify seedlings bred from resistant crosses which have inherited the resistance trait. Screening large numbers of seedling for this trait conventionally is expensive and laborious. Over 400 seedlings were screened in 2008. Seedlings can be positively selected for this trait and if successful in the further two generations of the program the resistance is confirmed using a conventional pot test. Use of marker aided selection has resulted in increased selection of *G. pallida* resistant seedlings at the advanced stage of the program and shows promise for the future. As markers become available they will be used more extensively in the breeding program

Disease resistance in new potato varieties

Disease resistance is an important objective of the potato-breeding programme and all advanced seedlings are tested for resistance to a wide range of commonly occurring diseases. Using standard laboratory and field techniques, testing commences when seedlings have completed their seventh year of propagation, and continues until a seedling is discarded or released as a new variety. During 2008 seedlings were tested for resistance to wart disease (*Synchytrium endobioticum*), foliage and tuber blight (*Phytophthora infestans*), common scab (*Streptomyces scabies*), dry-rot (*Fusarium caeruleum* and *F. sulphureum*), gangrene (*Phoma exigua* var. *foveata*), Rhizoctonia (*Rhizoctonia solani*), powdery scab *(Spongospora subterranea)*, potato virus X (PVX) and potato virus Y (PVY). Many of the new seedlings were found to possess high levels of disease resistance and could make a significant contribution to reducing disease losses and decreasing pesticide use in potato production.

During 2008, 37 seedlings were tested for field resistance to wart disease (*S. endobioticum*) and 11 were found to be susceptible. Seven advanced seedlings were also subjected to laboratory tests for resistance to wart disease. Of these, 1 exhibited the RG1 reaction and 2 exhibited the RG2 reaction while 4 seedlings were considered susceptible.

Testing for resistance to foliage blight (*Phytophthora infestans*) confirmed that the most resistant seedling was T2345/1; however, all seedlings tested were more susceptible than European standard resistant cultivars, Cara and Robijn.

The seedlings T3999/11, T3868/21, T3954/51, T2516/15, T3302/3, T2208a31 were highly resistant to dry rot (*F. caeruleum* and *sulphureum*) but the remaining seedlings were all susceptible to highly susceptible. Three seedlings (T2516/15, T3302/3, T3999/11) showed good resistance to gangrene (*P. foveata*), while most seedlings showed moderate to high levels of resistance to common scab (*S. scabies*).

All seedlings tested were highly susceptible to infection with PVY. T2516/15 and T3961/64 were extremely resistant to powdery scab *(Spongospora subterranea).*

It can be concluded from these results, that with the possible exception of PVY, all advanced seedlings show moderate to high levels of disease resistance and this should give these seedlings a distinct commercial advantage.

Physical mapping and sequencing of BAC clones to elucidate the complete sequence of the Gpa4 region is ongoing.

Life Cycle Analysis of Miscanthus Production in Ireland

Fitzgerald J., Finnan J., Burke J.I. ***RMIS No. 5675***

This project was funded by the Department of Agriculture Research Stimulus Fund.

There has already been research quantifying the potential life-cycle greenhouse gas reductions of energy crop electricity. It was found that if 30% of peat and 10% of coal was replaced with co-fired miscanthus and willow respectively, savings of 1.9MT CO_2 eq a^{-1} could be made, which represents 2.8% of Irelands total emissions for 2004.

Large scale deployment of bioenergy crops such as miscanthus would require landscape-scale change and the environmental and social consequences of such a change are not fully understood. In the face of population growth and climate change, questions have been asked as to the wisdom of dedicating land resources to energy crops. However, Ireland is in a unique position, possessing a large agricultural area relative to the population size and energy from miscanthus has much to offer being renewable and close to carbon-neutral. This work aims to quantify the major environmental impacts associated with large-scale miscanthus cultivation. Impacts such as air quality, water quality, groundwater resources, energy balance, soil carbon, soil condition and biodiversity are being evaluated.

The methodology to be used in this study is known as life cycle assessment. It is a method for analysis and assessment of environmental impacts caused by product systems. The environmental life cycle of a product consists of all the stages from raw material extraction to its waste management. This study concentrates initially on a 'cradle to farm-gate' analysis i.e. the end-use of miscanthus will be focussed on later in the project. The approach to be taken here is known as consequential life-cycle assessment where the consequences of increased miscanthus production, and potential displacement of other agricultural crops and systems will be considered. This approach is useful with respect to evaluating the indirect local and global consequences of a course of action (Ekvall and Weidema, 2004).

The increased cultivation of miscanthus in Ireland would occur at the expense of other agricultural systems. This induces further consequences since it is assumed that the demand for a displaced crop or product will be compensated for by intensification, or by increasing imports of an equivalent crop or product from another country.

Energy Crops and Bio-remediation

Finnan, J., Rice, B., Ryan, D., Frohlich, A., and Galbally, P. ***RMIS No. 5543***

Restrictions on spreading industrial and municipal waste on food crops present an opportunity to energy crop growers who can attract additional income by offering their non-food crops for such uses. However, waste application introduces additional risk of nutrient loss and heavy metal contamination. The objective of this sub-project is to monitor nutrient losses and soil and water contamination after waste application to energy crops.

Two Miscanthus sites, each with three plots, were used for disposal of sewage sludge and brewery effluent in 2008. These plots had also been used for effluent disposal in 2007. Boreholes in the centre of each plot were used to give access to the underlying groundwater for sampling. Overland flow was monitored using collection channels and electronic monitors which recorded the time and duration of flow.

Some initial results are available which indicate higher levels of nitrogen and phosphorus in the overland flow from the Miscanthus plots which received the highest levels of brewery waste. Lower levels of nitrogen and phosphorus were measured in the overland flow from plots which received lower levels and no brewery waste. Differences in the nutrient content of overland flow were less obvious between the plots which received sewage sludge.

Thus far, there are no apparent trends in groundwater nitrate levels between treatments. However, higher concentrations of both potassium and phosphorus were measured in groundwater beneath plots which received both brewery waste and sewage sludge (Table 1).

Table 1: Nutrient concentrations in groundwater

Plot Name and Treatment level	Sewage (control)	Sewage (light app)	Sewage (heavy app)	Brewery (control)	Brewery (light app)	Brewery (heavy app)
Summed Nitrate in GW (mg/l)	*119.1*	*78.0*	*125.0*	160.7	73.8	122.3
Summed K in GW (mg/l)	*8.97*	*7.40*	*30.77*	13.8	15.9	908.3
Summed P in GW (mg/l)	*0.8*	*0.8*	*2.0*	0.7	1.1	5.3
Total Waste Spread (t)	0	4.0	5.9	0	29	58

Some initial trends are evident from the analysis of metals in groundwater. Higher concentrations of metal were recorded in groundwater underneath Miscanthus plots which received applications of brewery effluent, concentrations of copper and zinc in groundwater increased with increasing concentrations of brewery effluent although this trend was not evident for lead, cadmium or chromium (Table 2). There are no discernible trends thus far in groundwater metal concentrations below plots which received sewage sludge.

Table 2: Metal concentrations in groundwater

Plot Name and Treatment level	Sewage (control)	Sewage (light)	Sewage (heavy)	Brewery (control)	Brewery (light)	Brewery (heavy)
Sum of all heavy metals in GW (mg/L)	276.0	256.8	258.7	*217.2*	*275.6*	*372.3*
Sum of all heavy metals spread on land (kg)	0.0	81.3	156.0	0.0	29.0	58.4
Copper (mg/ L)	*83.8*	*80.1*	*95.2*	*63.1*	*106.4*	*157.1*
Total Copper spread (kg)	0.0	19.1	38.4	0.0	19.1	38.4
Zinc (mg/L)	*50.8*	*51.4*	*43.1*	*19.0*	*47.3*	*49.1*
Total Zinc Spread on BF (kg)	0	37.3	72.7	0.0	27.2	55.3
Nickel (mg/L)	*31.9*	*27.7*	*32.6*	*33.6*	*37.3*	*43.0*
Total Nickel spread on NAM (kg)	0	2.9	5.8	0.0	2.8	5.7
Lead in NAM GW (mg/L)	*55.7*	*65.0*	*26.3*	*64.8*	*53.1*	*69.8*
Cadmium in NAM GW (mg/L)	*14.4*	*9.7*	*14.5*	*11.5*	*11.9*	*17.9*
Chromium in NAM GW (mg/L)	*39.4*	*22.9*	*47.1*	*25.2*	*19.5*	*35.3*
Total Pb, Cr, and Cd spread (kg)	0.0	11.2	21.9	0.0	7.5	15.1

Feasibility of production and combustion of pellets from straw and energy crops

Finnan, J., Carroll, J., Frohlich, A. and Brett, P. ***RMIS No. 5613***

The use of pellets from sawdust for home heating in Ireland is expanding rapidly. Sawdust has many advantages for pellet production, but its supply is limited and other feedstocks will soon be needed. Short-rotation willow, miscanthus, rape straw and cereal straws are all alternatives of interest to Irish farmers. Pelleting these materials, increases bulk density, which should make them suitable for use in a wide range of biomass boilers and stoves.
In this project begun in Oct 2006, pellets are currently being made from a range of energy crops, cereal and rape straws. The pellet ability of these materials and the suitability of the pellets as boiler and stove fuels are being examined. Combinations of willow and miscanthus (at varying percentages) and miscanthus and rape straw have been produced and show good results to date. Binding properties of willow and of rape cake add to overall durability of combination pellets.

Table 1: Pellet Properties

	Ash Content (%)	**Calorific Value (MJ/kg)**	**Durability (%)**
Willow	2	19.8	97.5
Rape Straw	8.2	19.6	96.8
Miscanthus	1.9	18.5	94.3
75% R.S.:25% M	7.2	19.2	96.1
50% R.S.:50% M.	5.9	18.9	95.4

Ash content of willow at approximately 2% is higher than wood pellets due to increased levels of bark in the samples. Energy content at 19.8 MJ/kg is very similar to that of commercially available wood pellets. Nitrogen and chlorine contents (less than 0.3% and 0.03% respectively) are at acceptable levels. Two different combinations of miscanthus and rape straw were tested and it was noted that increasing rape content increased ash but also had a positive effect on calorific value and durability. Higher miscanthus contents led to decreased ash but also poorer values in terms of energy content and durability (Table 1). Mixtures of miscanthus and willow were also tested and had intermediate levels in terms of ash (2.1%) and other chemical contents indicating that this process could be used to make the most of the best properties of one raw material to alleviate the worst properties of the second.

Pelleting and further testing of energy crops and cereal straws is ongoing and boiler trials to determine combustion efficiency and emissions levels are underway.

Producing Biomass for Energy

Finnan, J. ***RMIS No.5788***

The use of biomass as a source of energy forms a significant part of government strategy to reduce fossil fuel dependence and to mitigate the impact of climate change. However, energy crops and short rotation coppice have not been grown in this country to any significant extent and relatively little research work has been carried out in Ireland.

The objectives of this study are to;

1) Evaluate the potential of a range of energy grasses in Ireland.
2) Evaluate the effect of agronomic factors on the use of Hemp as a bioenergy feedstock.
3) Evaluate the biomass potential of new willow varieties.
4) Determine the optimum method for harvesting and drying whole stem willow.

5) Quantify *Miscanthus* harvesting losses and investigate the feasibility of reducing these losses by modifying existing machinery.

An evaluation of perennial grasses for Bioenergy

Energy crop trials were established during May 2008 at three sites; Oak Park, Knockbeg and at Johnstown Castle. The trials contained the following grasses;

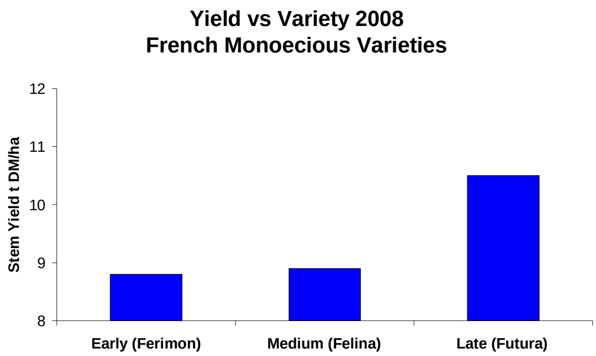
- Miscanthus
- Reed Canary Grass (varieties Bamse and Chiefton)
- Switchgrass (varieties Kanlow and Shawnee)
- Tall Fescue (variety Olga)
- Cocksfoot (variety Sparta)

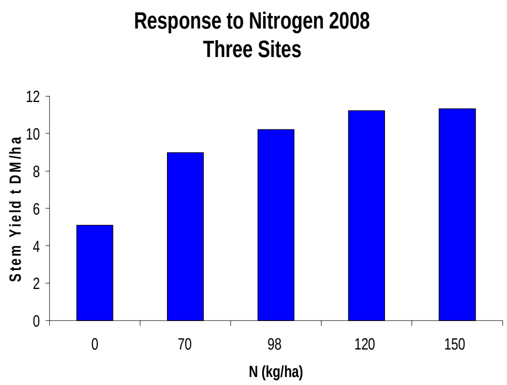
All grasses with the exception of switchgrass established well. Switchgrass, however, took considerably longer to emerge compared to other grasses and establishment was patchy. A switchgrass variety trial was sown during June 2008, varieties from the Northern US states proved to have better establishment and more even growth compared to varieties which originated in Southern US states.

An evaluation of hemp for bioenergy

Previous research at Oak Park proved that Hemp could produce high yields of stem dry matter in the Irish climate. Hemp has begun to attract interest as an energy crop both as a combustible material and as a feedstock for second generation ethanol since hemp fibres have a high cellulose content, 135 ha of the crop were grown in Ireland during 2008.

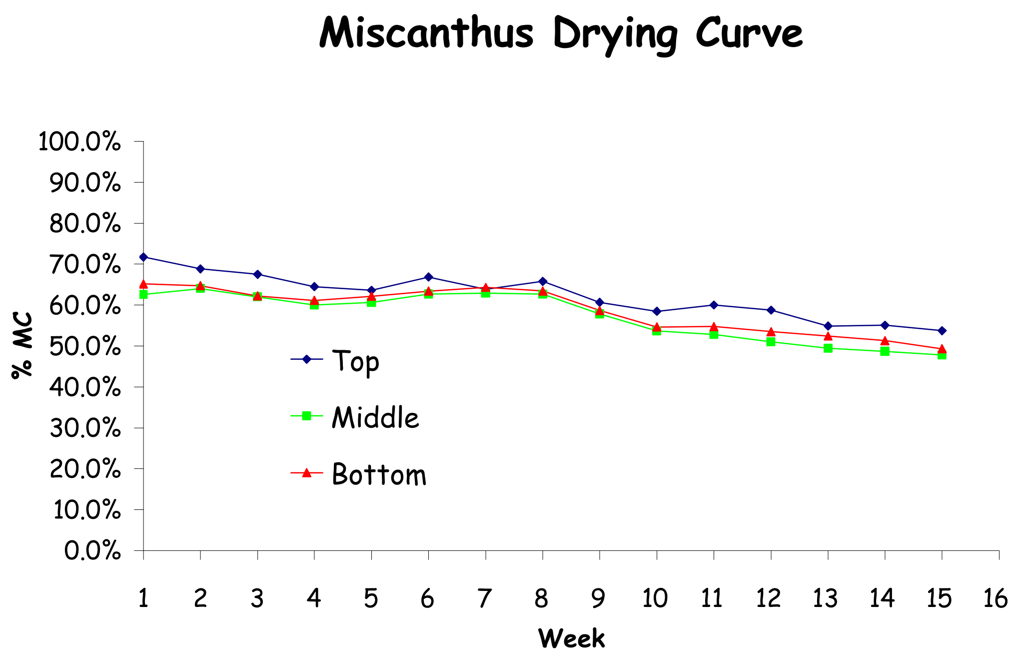
Three hemp trials were conducted at Oak Park, Knockbeg and near Edenderry to determine the optimum nitrogen levels for hemp and to investigate whether earlier harvesting could be achieved by the use of early maturing varieties. Variety and site did not have any impact on nitrogen response which exhibited a quadratic relationship, only very small yield increases could be achieved above an application rate of 120 kg N/ha. Early maturing varieties matured earlier but were significantly out yielded by late maturing varieties.





Optimisation of Miscanthus harvesting

Miscanthus can be harvested using conventional agricultural machinery but harvesting losses can be as high as 30%. Work commenced during 2008 to improve carbon capture from Miscanthus. Initial work has concentrated on understanding how Miscanthus dries during the winter period prior to harvest.



Field trials of the oilseed crop *Camelina sativa* and properties of the obtained oil

Frohlich, A. ***RMIS No. 5771***

Camelina oil obtained from commercial sources was characterised in terms of fatty acid profile and of tocopherol content. The obtained fatty acid profiles were very similar to those reported in the recent literature, but they had 4 % lower linolenic acid content than camelina oil extracted from seeds grown at Oak Park in 1998 and 1999. Relative amounts of tocopherols in the commercial and the Oak Park oils were very similar, but the total tocopherol contents were nearly double in the former. Phenolic antioxidants reported before were not determined at this stage.

Comparative oxidative stability of camelina oil, vis a vis the two most common commercial edible oils, rapeseed and sunflower oils were determined by accelerated storage (65oC, daily sampling) and thermal oxidation. The parameters monitored during accelerated storage were peroxide, fatty acid and water contents, p-anisidine value, tocopherol deactivation time, and changes in fatty acid composition. The rate of change of the monitored parameters during storage is thought to be proportional to the time elapsed before secondary oxidation begins (induction period), which is also the beginning of rancidity. Accelerated storage of camelina oil was carried out in triplicate and of rapeseed and sunflower oils in duplicate and each parameter was the average of the multiple determinations. Thermal induction times were determined by the Rancimat method at 110oC with 10l/hr air flow, four times for camelina and sunflower oil and twice for rapeseed oil.

Peroxide content, a measure of primary oxidation, increased over ten fold in the three oils during the seven days of oxidation, sunflower showed the highest increase and rapeseed the lowest. Tocopherol deactivation time is regarded as good indicator of lipid susceptibility to oxidation, and the levels of these antioxidants fell to below 10 mg/kg between six and eight days, again sunflower showed the highest rate of deactivation, whereas rapeseed oil the lowest. On the other hand camelina showed the largest increase in p-anisidine value, which measures the level of alkenals thought to be partly responsible for rancid flavour. Similarly camelina oil had the lowest thermal induction time, 2.7 hrs, followed by sunflower and rapeseed oils with 4.5 and 8.8 hrs respectively. There was only very small increase\in water and FFA contents during accelerated storage, hence these parameters were of little value for the evaluation of the resistance to oxidation of the particular oil.

Results obtained so far with accelerated storage and thermal induction times are inconclusive as to the relative stability of camelina oil. Rates of peroxide increase and tocopherol deactivation indicate that camelina is more stable than sunflower oil, whereas p-anisidine values, reduction in oxidation susceptible fatty acid contents, and thermal induction times indicate the opposite. The reason for the contradictory results is that each of these parameters determines a different aspect of oxidation It will need to be established by another method, probably by sensory analysis, which of these parameters are the most suitable indicators of the beginning of rancidity, and define the stability of camelina oil accordingly.

Evaluating Irish grassland as a source for bioenergy: Environmental impacts and long-term sustainability

Finnan, J. ***RMIS No. 5819***

This project investigates the suitability of Irish grassland, under a range of management intensities, for biogas production. Factors being studied to determine the suitability of grassland for biofuel production include grass quality, biogas yield, the full greenhouse gas balance, soil C and N dynamics, biodiversity and the energy required to produce, transport and process the biomass. A model will be developed to consolidate all the data obtained in the study to simulate the long-term sustainability of grassland for biogas production in Ireland. This will include an economic evaluation and a comparison with other recommended energy crops to provide an invaluable decision support system for policy makers and the farming community.

Three grassland sites were established during 2008, two at Johnstown Castle and one at Oak Park. Biomass and biogas yields were measured at all sites during the year in addition to greenhouse gas emissions. Measurements will continue during 2009.

Breeding improved varieties of perennial ryegrass

Conaghan, P. **_RMIS No. 4758_**

Grassland is the primary resource for almost all our agricultural output. About 90% of the farmed land in the country is devoted to grassland. The competitiveness of Irish agriculture is based on grassland providing a cheap and high quality feed source. While sward composition, especially for old pastures, is often complex, perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens*) are the key components of the most productive pastures. Genetic improvement of these species by breeding cultivars with superior yields of quality forage over a long grazing season provides a cost effective mechanism to increase the profitability and reduce the environmental cost of animal production from grassland.

The principal objectives of the grass breeding programme are to breed superior diploid and tetraploid perennial ryegrass cultivars with:

- Greater forage yield in spring and autumn
- Increased total annual forage yield
- Greater persistency
- Improved sward density
- Reduced stem in the aftermath regrowth
- Higher quality
- Better disease resistance

The selection procedure is based on full-sib progeny tests under sward conditions and is designed to bring the families under selection to the field plot stage as early as possible. Full-sib families derived from pair-crosses do not give enough seed for sowing plots. Each family is multiplied in isolation to give enough seed for such field trials. Field evaluation requires a minimum of 3 years, sowing year plus two harvest years. Selection is based on two cutting management regimes: frequent (8 harvests/year) and infrequent (4 harvests/year) cutting. Rust resistance is assessed in France. The superior families are intercrossed to produce new cultivars (synthetics). The newly created cultivars are evaluated at Oak Park and at several sites throughout Europe. Cultivars which show excellent performance are submitted to National List/Recommended List trials in the appropriate countries.

In 2008, three new cultivars were awarded Recommended Listing in Ireland and other countries:

KINTYRE (Breeder's reference R970354LT) – Late tetraploid *Lolium perenne* L. cultivar. *Recommended List Award.* Scotland (SAC) Recommended List 2008/09.

TYRCONNELL (Breeder's reference R970346LD) – Late diploid *Lolium perenne* L. cultivar. *Recommended List Award.* England and Wales (NIAB) Recommended List 2008/09.

TYRCONNELL (Breeder's reference R970346LD) – Late diploid *Lolium perenne* L. cultivar. *Recommended List Award.* Scotland (SAC) Recommended List 2008/09.

JANUARY (Breeder's reference R960342ED) – Early diploid *Lolium perenne* L. cultivar. *Recommended List Award.* Northern Ireland (DARD) Recommended List 2008/09.

JANUARY (Breeder's reference R960342ED) – Early diploid *Lolium perenne* L. cultivar. *Recommended List Award.* Ireland (DAF) Recommended List 2008.

Six cultivars were awarded National Listing in Ireland and other countries:

GIANT (Breeder's reference R970349MT) – Intermediate tetraploid *Lolium perenne* L. cultivar. *National List Award.* Ireland, 13 May 2008.

JANUARY (Breeder's reference R960342ED) – Early diploid *Lolium perenne* L. cultivar. *National List Award.* Ireland, 13 May 2008.

TYRCONNELL (Breeder's reference R970346LD) – Late diploid *Lolium perenne* L. cultivar. *National List Award.* United Kingdom, 19 August 2008.

GENESIS (Breeder's reference R990921ED) – Early diploid *Lolium perenne* L. cultivar. *National List Award.* Germany, 23 April 2008.

SOLOMON (Breeder's reference R990922MD) – Intermediate diploid tetraploid *Lolium perenne* L. cultivar. *National List Award.* United Kingdom, 1 April 2008.

MAJESTIC (Breeder's reference R980644LD) – Late diploid *Lolium perenne* L. cultivar. *National List Award.* United Kingdom, 1 April 2008.

GENESIS (Breeder's reference R990921ED) – Early diploid *Lolium perenne* L. cultivar. *National List Award.* United Kingdom, 1 April 2008.

In addition, four grants of Plant Breeders' Rights were awarded to the following cultivars:

PROSPEROUS (Breeder's reference R980641MD) – Early diploid *Lolium perenne* L. cultivar. *Grant of Plant Breeders' Rights.* United Kingdom, Grant no. 8024, 19 April 2008.

SOLOMON (Breeder's reference R990922MD) – Intermediate diploid *Lolium perenne* L. cultivar. *Grant of Plant Breeders' Rights.* United Kingdom, Grant no. 7954, 3 April 2008.

MAJESTIC (Breeder's reference R990922MD) – Late diploid *Lolium perenne* L. cultivar. *Grant of Plant Breeders' Rights.* United Kingdom, Grant no. 7955, 3 April 2008.

GENESIS (Breeder's reference R990921ED) – Early diploid *Lolium perenne* L. cultivar. *Grant of Plant Breeders' Rights.* United Kingdom, Grant no. 7956, 3 April 2008.

Herbage Breeding

To date the Teagasc grass breeding programme has bred and commercialised 18 new cultivars of perennial ryegrass. Summary details are as follows:

Maturity	Cultivar	Ploidy
Early	GENESIS	Diploid
	JANUARY	Diploid
	OAKPARK†	Diploid
	GREENISLE†	Tetraploid
Intermediate	CASHEL	Diploid
	SHANDON	Diploid
	SOLOMON	Diploid
	GIANT	Tetraploid
	GLENSTAL	Tetraploid
	GREENGOLD	Tetraploid
	MAGICIAN	Tetraploid
Late	MAJESTIC	Diploid
	TYRCONNELL	Diploid
	GLENCAR	Tetraploid
	KINTYRE	Tetraploid
	MILLENNIUM	Tetraploid
	SARSFIELD	Tetraploid
	ULYSSES†	Tetraploid

†Obsolete/outclassed

An additional 17 cultivars are still undergoing testing for National Listing/Recommended Listing in Ireland and other countries.

In tandem with the selection and release of new cultivars of perennial ryegrass, research focuses mainly on the development and testing of novel plant breeding methodology. In 2008 the findings of two research projects were completed and published.

Efficiency of indirect selection for dry matter yield based on fresh matter yield in perennial ryegrass sward plots

Conaghan, P., Casler, M.D., O'Kiely, P. and Dowley. L.,
Crop Science (2008), **48**: 127-133.

Abstract:
Forage dry matter yield (DMY) is a high-priority trait in breeding perennial ryegrass (Lolium perenne L.). However, determining dry matter concentration is highly labour intensive. For a similar level of resources indirect selection based on fresh matter yield (FMY) would allow a greater number of replicates, genotypes, or both to be evaluated. Our objective was to estimate the efficiency of indirect selection for DMY based on FMY of pure perennial ryegrass sward plots. Over a 14-year period, replicated trials, containing perennial ryegrass genotypes of similar ploidy and maturity category, were sown in Ireland and assessed for DMY and FMY at each harvest over 2 consecutive years. Forage was generally surface dry when harvested. The estimated efficiency of indirect selection based on two replicates and comparable selection intensity was high ($\geq$ 0.80). Simulation models indicated that resources would be utilized more efficiently by evaluating more genotypes than by increasing the number of replicates. For example, doubling the number of plots to increase the number of replicates from two to four indicated an increase in the efficiency of indirect selection from a

mean 0.88 to 0.94. However, doubling the number of plots and including more genotypes, facilitating greater selection intensity, indicated an increase in the efficiency of indirect selection from a mean 0.88 to 1.04. This study indicates that FMY can be successfully used as an indirect selection method of increasing DMY in perennial ryegrass swards.

Genotype × environment interactions for forage yield of perennial ryegrass sward plots in Ireland

Conaghan, P., Casler, M.D., McGilloway, D.A., O'Kiely, P., and Dowley. L., *Grass and Forage Science* (2008), **62**: 1-14.

Abstract:
Perennial ryegrass (Lolium perenne L.) is by far the most widely sown grass species in Ireland. Genotype × environment (G × E) interactions are a frequent occurrence in forage yield evaluations. The objectives were to determine (i) the nature and relative magnitudes of the pertinent G × E interaction variance components for forage dry matter yield of perennial ryegrass sward plots in Ireland and (ii) the optimal allocation of replicates, locations, and years in a testing program. Sixteen perennial ryegrass cultivars were sown at six locations throughout Ireland between 2000 and 2004. Plots from each sowing were harvested for 2 consecutive years under a simulated mixed grazing and conservation management program. The largest component of the G × E variance was generally genotype × location × year emphasizing the need for evaluation of genotypes across locations and years in order to adequately characterize genotypes for differences in yield. Relative differences among genotypes from year to year and location to location were due mainly to changes in genotype rankings. Weather was estimated to have a greater effect on annual variation than age-of-stand. The optimum allocation of resources for a testing program was estimated at four replicates per location, and either two locations and 3 sowing years or three locations and 2 sowing years with 2 harvest years for each sowing year. The most appropriate option depends on the relative importance of time vs. financial resources.

Breeding improved varieties of white clover

Conaghan, P. ***RMIS No. 4755***

White clover (*Trifolium repens*) benefits grassland agriculture through its ability to fix nitrogen, its high nutritive value, its seasonal complementarity with grass, and its ability to improve animal feed intake and utilisation rates. Therefore, including white clover in the sward tends to build and maintain soil fertility, improve individual animal performance and reduce production costs. Cultivars that are persistent, high yielding and adapted to a range of managements are required to underpin the exploitation of good grass/clover production systems.

The principal objectives of the white clover breeding programme are to breed superior varieties of small, medium and large leaf size with:

- Greater persistency
- Increased total annual yield
- Improved seasonal yield in spring and autumn
- Higher stolon density
- Better disease/pest resistance
- Good seed production

The selection procedure is based on full-sib progeny tests in mixed grass/clover swards. The system is designed to bring the families under selection to the field plot stage as early as possible in the selection programme.

The families are evaluated under three managements:

1. Yield assessment in competition with grass,
2. Persistence measurement in competition with grass,
3. Seed yield potential in clover plots only.

Separate trials must be established for each management. The superior families are intercrossed to produce new cultivars (synthetics). The newly created cultivars are evaluated at Oak Park and at several sites throughout Europe. Cultivars which show excellent performance are submitted to National List/Recommended List trials in the appropriate countries.

In 2008, one new cultivar was granted Plant Breeders' Rights:

EXCALIBUR (Breeder's reference W980105) – Medium leaf *Trifolium repens* cultivar. *Grant of Plant Breeders' Rights.* United Kingdom, Grant no. 7647, 19 July 2008.

Five new white clover cultivars were accepted for inclusion in the National List/Recommended List trials in Ireland following excellent performance at Oak Park. In total 11 cultivars are undergoing testing for National Listing/Recommended Listing in Ireland and other countries.

To date the Teagasc clover breeding programme has bred and commercialised eight new cultivars of white clover. Summary details are as follows:

Leaf size	**Cultivar**
Small	GALWAY PIROUETTE TARA†
Medium	AVOCA CHIEFTAIN SUSI
Large	ARAN

†Obsolete/outclassed

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