

# Results from an arable crop rotation study at Oak Park 2000 - 2007

*Study was undertaken by J. G. Crowley, A. Mahon and E. Baldwin*

*Report prepared by T. Kennedy<sup>1</sup>, C. Merfield<sup>2</sup> and A. Mahon<sup>1</sup>*  
*Teagasc*

*<sup>1</sup>Crops Research Centre Oak Park,*

*<sup>2</sup>Environment Research Centre Johnstown Castle*

## Summary

An organic rotation trial was established at Oak Park in 2000. The crop sequence in the seven year rotation was: two years grass-clover, winter wheat, potatoes, winter oats, lupins and spring barley. The grass-clover, which supplies nitrogen to the system, also provides vegetation which of late is cut and mixed with cereal straw to produce compost. The compost replaced sheep manure which was available up to 2007. Manure was applied to potato plots prior to cultivation for the period 2002 to 2007 and to barley plots from 2005 to 2007. The average yield of crops over the period of the rotation was: winter wheat 5.9 t/ha, potatoes 32.7 t/ha, winter oats 5.8 t/ha, lupins 2.4 t/ha and spring barley 4.5 t/ha. Triticale, which was grown in one of the plots designated for winter wheat, had an average yield of 7.5 t/ha. Lupins have been unsatisfactory due to uncompetitiveness with weeds and lateness of maturity.

## Introduction

An organic crop rotation experiment was established at Oak Park Carlow in July 2000. The selected rotation which did not include livestock completed one full cycle in 2007. The overall objective of the experiment was 'to improve the yield and quality of organic arable crops in Ireland'.

## Methods

*The site:* The trial site soil is a deep heavy textured, well drained, Grey-Brown podzolic (22-25% clay) capable of producing high crop yields. Prior to organic conversion, the area was under grass for about 10 years.

*Rotation:* The seven year rotation had the following crops; two years grass-clover, winter wheat, potatoes, winter oats, lupins and spring barley. The seven plots, one for each year/crop of the rotation, were randomly positioned within a block. There were three blocks (replicates), two of which had plots of size 0.32 ha with plots of the remaining replicate of size 0.2 ha. Triticale was grown in one of the plots designated for winter wheat each season with the exception of 2004. In 2003 winter wheat failed to establish in one plot and was replaced with spring wheat. From autumn 2006, the trial site was used by DAFF as one of four country wide organic sites for cereal cultivar evaluation. Cultivars of either wheat/triticale, oats or barley were evaluated by DAFF in small plots (3.3 x 12 m, having five-fold replication) within a single large plot of the same cereal. The cultivar data from the Oak Park site together

with data from other sites contributes to a more comprehensive and reliable assessment of individual cultivars.

## Results

### *Grass-Clover*

The grass-clover seed mixture sown in the period 2000 to 2003 is given in Table 1. In general, the establishment of grass-clover plants when under-sown into barley was considered poor and in 2005 the grass-clover failed to produce adequate plant populations. After 2005, grass-clover was sown directly into freshly cultivated soil during early autumn following harvesting of the barley. The white clover was replaced by red clover (cv Merviot) in autumn 2006 because establishment of the white clover crop had been poor. In the period 2000 to 2006 the grass-clover was mulched into the plots by frequent cutting, thereafter it was cut twice per year and mixed with straw from the cereal plots to produce compost for subsequent application to soil prior to sowing the potato and barley crops.

**Table 1.** The grass-clover seed mix, kg/ha, 2000 to 2003.

Crop	Cultivar	Heading date	kg/ha
Grass (perennial)	Greengold (tetraploid)	Mid-season	9.8
Grass (perennial)	Tivoli (tetraploid)	Late-season	9.8
Grass (perennial)	Spelga (diploid)	Mid-season	5.2
Clover (white)	Avoca	-	2.6
Clover (white)	Aran	-	1.6

The mixture used from 2004 to 2006 is given in Table 2.

**Table 2.** Grass-clover seed mix, 2004 to 2006.

Crop	Cultivar	kg/ha
Grass (perennial)	Magician	6.2
Grass (perennial)	Cashel	10.4
Clover (white)	Avoca	5.2
Clover (white)	Aran	5.2

### *Winter wheat and triticale*

A number of wheat cultivars (varieties) were evaluated in the period 2002 to 2007. In general, yields were good for the top yielding cultivars which, over the rotation cycle, had an average yield of 7.37 t/ha and a range of 6.02 to 8.24 t/ha (15% moisture content), Table 3 and Appendix 1. The seasonal minimum yields for the lowest

yielding cultivars over the six year period ranged from 3.22 to 7.78 t/ha. The average seasonal yield for all winter wheat cultivars investigated was 5.93 t/ha. Best yielding cultivar per season, 2002 to 2007, respectively, were Exsept, Robigus, Claire, Deben, Deben and Timber. In the case where cultivars were evaluated for more than one season there was surprising variation in yield; for example the cultivar Exsept yielded best in 2002 but had the lowest yield for the cultivars evaluated in 2003.

The results of a seeding rate trial, 2001/2002, showed that yields increased with increasing seeding rate. The maximum seed rate of 225 kg/ha (14.5 st/ac) yielded 6.38 t/ha, Table 4. Three cultivars of spring wheat were evaluated in 2003. Grain yields ranged from 5.43 to 5.79 t/ha, Table 5.

The results of grain yields for six cultivars of triticale grown in 2003 are given in Table 6. Yields ranged from 6.71 to 8.66 t/ha. The top yielding cultivar was Cylus. Fidelio was grown in four seasons, 2002, 2003, 2005 and 2006 and had an average yield of 6.85 t/ha. Results of DAFF evaluation of twelve triticale cultivars at the site in 2007 showed an average yield for cultivars of 4.14 t/ha. The best yielding cultivars were: Versus, Tremplin, Bienvenu and Amarillo which yielded 5.06, 4.69, 4.61 and 4.57 t/ha, respectively.

**Table 3.** Grain yields, t/ha, and plant heights of winter wheat cultivars organic rotation trial Oak Park, 2002 – 2007.

Year	No cultivars	<sup>1</sup> Yield, t/ha			Plant height (cm)
		Minimum	Maximum	Mean	Range
2002	15	4.12	8.24	5.40	72 - 95
2003	10	5.58	8.00	6.80	73 - 87
2004	2	7.78	7.88	7.83	-
2005	1	6.02	6.02	6.02	98
2006	1	6.87	6.87	6.87	90
2007	14	3.22	7.18	5.53	45 - 55

<sup>1</sup>15% moisture content (MC)

**Table 4.** The effect of seeding rate on yield, t/ha, of winter wheat, cv Soissons, organic rotation trial, Oak Park, 2001/2002

Seeding rate seed/m <sup>2</sup>	kg/ha	(Stone/acre)	Yield, t/ha, 15% MC
300	135	(8½)	5.77
350	157.5	(10)	5.99
400	180	(11½)	6.04
450	202.5	(13)	6.10
500	225	(14½)	6.38

**Table 5** Spring wheat yield, t/ha, and plant heights (cm) 2003.

<b>Cultivar</b>	<b><sup>1</sup>Yield t/ha</b>	<b>Height cm</b>
Alexandria	5.79	54
Baldus	5.65	56
Raffels	5.43	57
<b>Mean</b>	<b>5.62</b>	<b>55.7</b>

<sup>1</sup>15% moisture content.

**Table 6** Triticale cultivars, yield, t/ha, and plant heights (cm) 2003.

<b>Cultivar</b>	<b><sup>1</sup>Yield t/ha</b>	<b>Height cm</b>
Cylus	8.66	117
Fidelio	7.95	108
Versus	7.71	115
Bienvenue	7.28	100
Lupus	7.04	126
Taurus	6.71	114
<b>Minimum - Maximum</b>	<b>6.71 – 8.66</b>	<b>100 - 126</b>
<b>Mean</b>	<b>7.56</b>	<b>113.3</b>

<sup>1</sup>15% moisture content.

### *Potatoes*

In the period 2003 to 2007 sheep manure (F.Y.M.) was applied to potato plots prior to tilling at the rate of 50 t/ha. Potatoes were sown at a tuber spacing of 30 cm. Three potato cultivars were sown each season between 2002 and 2007. These were Cara, Orla, and Setanta in 2002 and 2003, thereafter Cara was replaced with Sante. Orla, which is a 'second-early' has good tuber blight resistance. Setanta, a 'main-crop' cultivar also has good blight resistance. The cultivar Sante is an early 'main-crop' and is considered suited for organic growing since in addition to blight resistance it also has resistance to eelworm (PCN) and powdery scab. Weed control during the crop establishment phase of growth was achieved by hoeing and mould-ploughing. In general, weeds were not a problem. The average yield of tubers over the six seasons was 32.7 t/ha (Table 7) ranging from 26 to 45.7 t/ha, Table 8. The seasonal yields for each of the three cultivars are given in Table 8. Sante was found to have considerably greater resistance to slug damage when compared with either of the other two cultivars.

**Table 7.** Potato cultivar experiments 2002 to 2007: results by year including percentage breakdown of size grades by weight.

Year	< 40 mm	40-50 mm	45-60 mm	60-80 mm	> 80 mm	Discards	DM %	Yield t/ha
2002	9%	10%	61%	20%			24.4	28.3
2003	14%	16%	57%	10%		3%	23.1	26.0
2004	5%	7%	53%	32%	2%	1%	23.1	45.7
2005	2%	32%	37%	27%	1%	2%	23.2	37.3
2006	7%	8%	51%	29%	2%	5%	22.3	27.8
2007	2%	18%	73%	3%	0%	4%	21.0	30.9
<b>Mean</b>	<b>7%</b>	<b>15%</b>	<b>55%</b>	<b>20%</b>	<b>1%</b>	<b>3%</b>	<b>22.9</b>	<b>32.7</b>

**Table 8.** Potato cultivar experiments 2002 to 2007: overall yield results including percentage breakdown of size grades by weight.

Year	CV	< 40 mm	40-50 mm	45-60 mm	60-80 mm	> 80 mm	Discards	DM %	Yield t/ha
<b>2002</b>	<b>Cara</b>	10%	9%	59%	22%			25.1	28.2
	<b>Orla</b>	14%	15%	61%	10%			21.3	22.9
	<b>Setanta</b>	5%	5%	63%	27%			26.8	33.9
<b>2003</b>	<b>Cara</b>	17%	18%	54%	7%		4%	20.5	24.1
	<b>Orla</b>	15%	15%	59%	9%		3%	21	27.8
	<b>Setanta</b>	10%	14%	58%	15%		2%	27.6	26.2
<b>2004</b>	<b>Orla</b>	5%	7%	53%	34%	1%	1%	21.8	44.9
	<b>Sante</b>	8%	11%	63%	16%	0%	1%	24.7	42.5
	<b>Setanta</b>	2%	3%	44%	47%	4%	1%	22.9	49.6
<b>2005</b>	<b>Orla</b>	1%	24%	39%	33%	0%	1%	21.3	41.4
	<b>Sante</b>	4%	50%	33%	9%	0%	2%	23.7	35.9
	<b>Setanta</b>	1%	21%	38%	38%	2%	2%	24.6	34.5
<b>2006</b>	<b>Orla</b>	6%	8%	60%	17%	0%	8%	20.9	22.1
	<b>Sante</b>	10%	12%	62%	13%	0%	4%	24.2	26.3
	<b>Setanta</b>	3%	2%	31%	56%	5%	2%	21.8	35.0
<b>2007</b>	<b>Orla</b>	2%	19%	71%	3%	0%	6%	18.6	29.5
	<b>Sante</b>	2%	16%	73%	6%	0%	3%	20.8	37.0
	<b>Setanta</b>	2%	19%	75%	1%	0%	3%	23.5	26.3
<b>Overall mean</b>		<b>7%</b>	<b>15%</b>	<b>55%</b>	<b>20%</b>	<b>1%</b>	<b>3%</b>	<b>22.8</b>	<b>32.7</b>

### *Oats*

In 2002 and 2003 both cultivar and seeding rate trials were undertaken, thereafter only cultivar trials were conducted. The results of oat cultivar trials are given in Table 9. The low yields obtained in 2003 were as a consequence of the crop being sown on 20 March 2003; the delay resulting from unsuitable sowing conditions during the preceding season. The crop sown 13 November 2006 had extremely poor plant establishment due to various factors including crow damage. These plots were

ploughed-up in spring and sown with spring oat cultivars. The average grain yield of winter oats was 5.81 t/ha when the data for 2003 is omitted. The yield range was 4.52 to 7.24 t/ha (Table 9). The cultivar Jalna out-yielded Barra in the three seasons for which comparisons were made. Increasing the seeding rate of winter oats in the range 145 to 232 kg/ha, in 2002, did not produce commensurate grain yields, Table 10. A similar result was recorded in 2003. Spring oats, grown in 2007, had an average yield of 4.64 t/ha. Of the ten spring oat cultivars evaluated by DAFF at the site in 2007 Kaplan and Corrib were best.

**Table 9.** Oat cultivar comparison trials' results 2002 to 2007, Oak Park. WO = winter oats, SO = oats sown in spring.

Year	Crop	Cultivar	<sup>b</sup> Yield t/ha	Height (cm)
2002	WO	Barra	7.24	-
2003 <sup>a</sup>	SO	Barra	2.27	77
	SO	Freddy	2.48	70
	SO	Evita	1.91	68
	SO	Mixture	1.80	69
	WO	Barra	5.74	
2004	WO	Jalna	6.69	
	WO	Barra	4.99	132
2005	WO	Jalna	5.65	120
	WO	Barra	4.52	133
2006	WO	Jalna	5.84	132
	<b>WO</b>	<b>Mean</b>	<b>4.46</b>	<b>100.1</b>
2007	SO	Corrib	4.53	97
	SO	Evita	4.34	90
	SO	Freddy	4.52	89
	SO	Husky	4.68	87
	SO	Nord	5.12	90
	<b>SO</b>	<b>Mean</b>	<b>4.64</b>	<b>91</b>

<sup>a</sup>Sown 20 March 2003. <sup>1</sup>15% moisture content.

**Table 10.** Oat seeding rate trial results, cv Barra, Oak Park, 2002.

Seeding rate kg/ha	Stone/acre	<sup>1</sup> Yield t/ha
145	9.2	6.55
160	10.2	6.86
174	11.1	6.96
189	12.0	6.95
203	12.9	6.68
218	13.9	6.73
232	14.8	7.15

<sup>1</sup>15% moisture content (MC)

### *Lupins*

Lupins are a leguminous crop grown for its high protein content and nitrogen fixing ability. The main cultivars grown included the multi-branched types Borlenna, Bordako, Erantis, Galant, Kompolit, SNS and V6-1. The single stem cultivars were Borweta, Prima and Viol. Seeding rate was determined by 1000 kernel weight but commonly was in the region of 168 kg/ha. A seeding rate trial with the cultivars Prima and Borweta was sown 30 April 2003.

The results of investigations on lupin cultivars are given in Table 11. The mean yield of lupin grain was 2.43 t/ha and a range of 0.74 to 5.04 t/ha. The mean moisture content of grain at harvest was 31.4% (range 15.8% to 41.9%). The seeding rate trial showed that increased seeding rate resulted in increased grain yield and decreased moisture content of grain, Table 12. The relationship (regression value) between seeding rate and yield for the cultivars Borweta and Prima was  $R^2 = 0.99$  and  $0.94$ , respectively, while that for moisture content was  $R^2 = 0.94$  and  $0.80$ . Lupins are now considered an unsuitable crop for inclusion in an organic rotation in Ireland. The main problems encountered were uncompetitiveness of the crop with weeds and the lateness of maturity of grain resulting in late-autumn harvesting of the crop.

**Table 11.** Lupin cultivar experiments' results: yield t/ha at 15% dry matter.

Cultivar	2002	2003	2004	2005	2006	2007	Means	
							t/ha	Moisture %
Barlenna		5.04					<b>5.04</b>	25.2
Bordako	2.98	4.00		2.80	1.97		<b>2.94</b>	28.8
Borweta		3.39					<b>3.39</b>	15.8
Erantis						0.74	<b>0.74</b>	34.6
Galant						2.00	<b>2.00</b>	39.1
Kompolit						2.16	<b>2.16</b>	41.9
Prima	2.70	2.78	1.17				<b>2.21</b>	20.0
SNS						2.72	<b>2.72</b>	33.4
V6-1						2.21	<b>2.21</b>	40.2
Viol						0.93	<b>0.93</b>	34.9
<b>Year Mean</b>	<b>2.84</b>	<b>3.80</b>	<b>1.17</b>	<b>2.80</b>	<b>1.97</b>	<b>1.79</b>	<b>2.43</b>	<b>31.4</b>

**Table 12.** Lupin seeding rate and cultivar yields, t/ha, 2003.

Cultivar	Seeding rate kg/ha	Yield, t/ha, 15% MC
Borweta	100	2.61
	125	3.12
	150	3.63
	175	4.08
Prima	100	1.97
	125	2.35
	150	2.98
	175	3.09

### *Spring barley*

Spring barley was first planted in the rotation in 2003. Investigations in the first five seasons involved cultivar evaluation and the impact of seeding rates on grain yield. Sheep manure was applied to barley plots, prior to cultivation, at a rate of 25 t/ha in the period 2005 to 2007 inclusive. The average grain yields for spring barley in each season for the period 2003 to 2007 are given in Table 13. The average yield over this period was 4.49 t/ha (range 3.11 to 5.81 t/ha). It is possible yields could have been greater had the preceding crop being other than lupins since the extensive weed infestation in lupins undoubtedly contributed to weed prevalence in the barley crop. Of late, DAFF have conducted cultivar evaluations in barley plots. In 2007, 15 cultivars were evaluated of which the better yielding cultivars were; Cocktail, Sweeney, Frontier, and Publican yielding 5.32, 5.12, 4.81 and 4.81 t/ha, respectively. The yields at Oak Park have been better than at other sites (Appendix 2). The ranking of cultivars, based on yield, at Oak Park is broadly similar to that recorded at other sites. The effects of date of under-sowing grass-clover on barley grain yield and grass vegetation mass post crop harvest were measured in 2003. There was no difference in grain yield between plots sown with grass-clover at either 13 days or 24 days post sowing of barley. However, the mass of vegetation measured three months post crop harvest was greater for that sown at 13 days when compared with that sown at 24 days. The practice of under-sowing grass-clover into barley has been discontinued in favour of sowing in autumn.

### *Soil Nutrients*

The soil nutrient analysis for the period 2002 to 2006 are given in Table 14. The only source of added nutrients was sheep manure (until 2007). No major decline in nutrients has occurred.

New proposals for research on organic arable crops are currently being considered.



**Table 13.** The grain yield, t/ha, of spring barley, 2003 to 2007, Oak Park.

Year	Cultivar	<sup>1</sup> Grain yield t/ha
2003	Tavern	5.81
2004	Tavern	4.35
2005	Tavern	3.11
2006	Tavern	4.50
2007	Mean of 15 cultivars	4.71
<b>Overall mean</b>		<b>4.49</b>

<sup>1</sup>15% moisture content.

**Table 14.** Soil nutrient analysis by year, mg/kg

Year	pH	OM%	P	K	Mg	Cu	Zn	Mn	S
2002	6.92	5.76	11.61	121	198	3.52	3.25	343	-
2003	6.89	5.97	10.94	124	200	3.56	3.76	366	
2004	6.80	5.40	13.80	154	215	4.08	3.77	403	12.76
2005	7.06	-	10.00	122	215	-	-	-	-
2006	7.07	-	12.76	118	169	4.81	4.05	449	
Mean	<b>6.95</b>	<b>5.71</b>	<b>11.82</b>	<b>128</b>	<b>199</b>	<b>3.99</b>	<b>3.71</b>	<b>390</b>	<b>12.76</b>

**Appendix 2.** The grain yield, t/ha, spring barley cultivars, 2007, Oak Park as well as average yield from sites at Cork, Galway, Carlow and Wexford. Source: DAFF.

Cultivar	Yield, t/ha	
	<u>Oak Park</u>	<u>Average of 4 Sites</u>
Cocktail	5.32	3.91
Sweeney	5.12	3.95
Frontier	4.81	3.91
Publican	4.81	3.91
Sabastian	4.91	3.83
Christina	5.06	3.83
Jolika	4.96	3.72
Wicket	4.76	3.60
Snakebite	5.01	3.79
Eunova	5.27	3.79
Quench	4.96	3.87
Tamise	4.91	3.72
Centurion	5.06	3.68
Doyen	5.12	3.60
Spotlight	4.96	3.68
<b>Mean</b>	<b>5.00</b>	<b>3.78</b>

**Appendix 1.** Summary of winter wheat cultivar comparison trials, 2002 to 2007

Cultivar	Year	*Yield t/ha	TGW g	Height cm
Carlton	2002	5.04	32.5	75
Claire	2002	5.50	33.1	81
Deben	2002	5.90	35.1	85
Equinox	2002	4.29	26.5	83
Exsept	2002	8.24	49.6	94
Falstaff	2002	4.70	31.8	95
Goodwood	2002	5.28	31.1	80
Ld 91-59-1	2002	4.52	33.6	72
Madrigal	2002	5.56	33.6	78
Marshall	2002	5.26	31.5	91
Milestone	2002	5.98	32.3	95
Savannah	2002	5.20	33.0	79
Tanker	2002	4.12	29.0	83
Trust	2002	5.60	35.5	87
Xi 19	2002	5.78	35.8	90
Access	2003	6.14	33.3	74
Deben	2003	7.32	35.9	87
Dick	2003	6.45	N/a	78
Exsept	2003	5.58	N/a	80
Marshall	2003	7.01	36.9	82
Option	2003	6.44	35.8	79
Robigus	2003	8.00	35.8	79
Victor	2003	7.37	39.7	73
Welford	2003	6.93	31.2	74
Xi 19	2003	6.74	42.3	83
Claire	2004	7.88	46.3	N/a
Deben	2004	7.78	51.5	N/a
Deben	2005	6.02	42.1	98
Deben	2006	6.87	50.3	90
Alceste	2007	3.26	49.0	49
Alchemy	2007	6.33	53.6	54
Claire	2007	7.02	51.1	51
Cordial	2007	3.22	47.4	47
Cordial + Alceste	2007	4.80	54.8	55
Einstein	2007	5.76	52.9	53
Glasgow	2007	6.12	44.6	45
Gulliver	2007	4.59	50.5	51
Hyperion	2007	5.66	48.5	49
Lion	2007	6.67	48.5	49
Robigus	2007	4.95	47.4	47
Savannah	2007	6.13	49.9	50
Soltice	2007	5.84	49.3	49
Timber	2007	7.18	52.0	52
<b>Minimum</b>		<b>3.22</b>	<b>26.5</b>	<b>45</b>
<b>Maximum</b>		<b>8.24</b>	<b>54.8</b>	<b>98</b>
<b>Mean</b>		<b>5.93</b>	<b>41.09</b>	<b>71.85</b>

\*15 % Moisture content.