An evaluation of the potential impact the loss of chlorothalonil may have on the productivity of winter wheat and spring and winter barley grown in Ireland

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Summary

Currently chlorothalonil plays a vital role in disease control in Irish cereal production systems. Whilst previously it has been used as an anti-resistance strategy to prolong the efficacy of the main fungicides used to prevent wet weather diseases, in recent years it has played an increasing important and direct role in disease control and maintaining potential yields. To determine its value in current systems and to project how the potential removal of chlorothalonil may impact on the production and profitability of Irish winter wheat, spring and winter barley trials conducted by Teagasc both internally and on commercial contracts were reviewed to identify treatments where direct comparisons of +/- chlorothalonil were conducted. To undertake this exercise the 2016 and 2017 (a small number of trials from the 2018 season were also included) seasons were selected. Both seasons were regarded as moderate disease pressure seasons, but equally they represent the most recent seasons whereby impacts of resistance in the target diseases (Septoria on wheat and Ramularia on barley) could be determined. Using these comparisons predicted yield losses were calculated and combined with potential disease control programmes that are likely to be used to determine the impacts on costs of production over a range of potential yields and net margins of production based on both the 2016 and 2017 seasons. Based on the most likely outcomes for each potential disease control programme significant increases in the cost of producing a tonne winter wheat or barley can be expected. Such increases adversely impact on the net margin for producing that crop and depending on the price of grain this may be a dramatic reduction.

Conclusions

- Where chlorothalonil is not available this report estimates the most likely scenario for e-Profit Monitor farmers is an average Net Margin reduction of over 50% in wheat and 65% in barley, with growers achieving national average yields at or just above break even. Figures are based on the Teagasc e-Profit Monitor 2016-2017.
- Cereal production will only be economic on the highest yielding sites with low costs of production as the risks of economic loss will increase dramatically on other sites.

- Irish growers will lose competitiveness as it is anticipated that other regions outside Ireland will not suffer the same losses, and consequently grain prices will not rise in Ireland to offset yield losses.
- In the medium term the introduction of new fungicides will be welcome and increase disease control options, however in the absence of chlorothalonil a more rapid loss of efficacy of these fungicides is expected due to high disease pressure.

Objectives

This report sets out to critically assess data generated by Teagasc within the Crop Science Department for the potential losses in productivity that may occur in Irish winter wheat and winter and spring barley production systems if the fungicide chlorothalonil (CTL) is removed from the market. This report specifically deals with potential yields losses of winter wheat, winter and spring barley and does not take into account the wider ramifications on the entire production system – loss of cereal production or changes to alternative crops etc. To assess the impact the most recent seasons 2016 and 2017 were selected. These years represent moderate disease pressures, but equally represent are the most representative of current Septoria and fungicide sensitivity status. Limited data for 2018 is included for winter barley to account for recent changes in fungicide resistance that have occurred in Ramularia populations.

Wheat Data Analysis – Septoria specific

Crop protection trials conducted by Teagasc both internally and on contract on winter wheat during the 2016 and 2017 growing seasons were reviewed and treatments where direct comparisons of +/- CTL were recorded. All trials were laid out as randomised block designs and yields harvested using a plot combine and adjusted to 15% moisture.

In both seasons the winter wheat trials were conducted at trials sites at Teagasc Oak Park, Knockbeg research site and Bellewestown Co. Meath. Only trials where comparisons of foliar applications (GS31-55) could be made were evaluated. A total of 17 trials, in which 55 direct comparisons of +/- CTL could be determined were deemed useable. In all cases the CTL product used was Bravo 500 (chlorothalonil 500g/l) and was applied at a rate of 1.0 l/ha. 80% of these included current market standards with regards available fungicides (SDHI/azole mixtures) and were applied at 80-100% the recommended label rate. 9% were developmental chemistries, with the remaining 11% a combination of solo azoles or azole mixtures. In all trials Septoria was the target pathogen and moderate levels were reported in each season. Whilst only an analysis of yields has been conducted for this report as a strong correlation exists between levels of STB infection and yield loss the data within is reflective of STB control. Yields (15% moisture) from the plots of the treatments selected and the untreated control plots in each of the 17 trials were extracted and

analysed by regression in Genstat to determine the impact of CTL on overall yields. The range in the loss of yield observed, % loss in yield (calculated based on a potential yield where CTL was included), and potential loss in earnings/ha were plotted.

To evaluate how the loss of CTL may impact the economics of growing winter wheat the range of % yield loss was used to calculate the mean, median, maximum, minimum, upper quartile and lower quartile losses and these were used in combination with the costs of production as set out in the Teagasc Crops Costs and Returns 2018. The impacts of the above losses in yield was used to estimate increased cost in production/tonne over a range of predicted yields. To project how these reductions may impact on net margins of production they were applied to the eProfit monitor data for both the average and top 1/3 of winter wheat producers in both 2016 and 2017. In all analysis three potential disease control scenarios which will impact on total variable costs of production per ha were evaluated:

1. Continued fungicide programme – total costs of production per ha reduced by €20/ha to reflect loss of CTL in programme
2. Addition of folpet to fungicide programme – total costs of production per ha increased by €6/ha, taking into account the additional costs above cost of including CTL in a programme. As of 2018 folpet is the only other multsite alternative registered for usage in Irish winter wheat crops between GS31-55 and as such is complementary to current fungicide programmes.
3. Additional of folpet to fungicide programme and increased application rates and additional QoI treatment – total costs of production per ha increased by €77/ha

Potential impacts on winter wheat yields and cost of production and net margins of production

Within the trials data set the addition of CTL to fungicide programmes had a significant impact on yield, adding on average 0.58 t/ha, however this ranged from 1.73 t/ha to -0.25 t/ha (Fig 1). The addition of CTL was positive in 51 of the 55 comparisons. In the four cases where a yield loss was experienced they included a fungicide under development in which a 2.5 tonne yield response was recorded and two where potential antagonism with prothioconazole may have been experienced. This represents on average a yield loss of 6.69%, but a range from

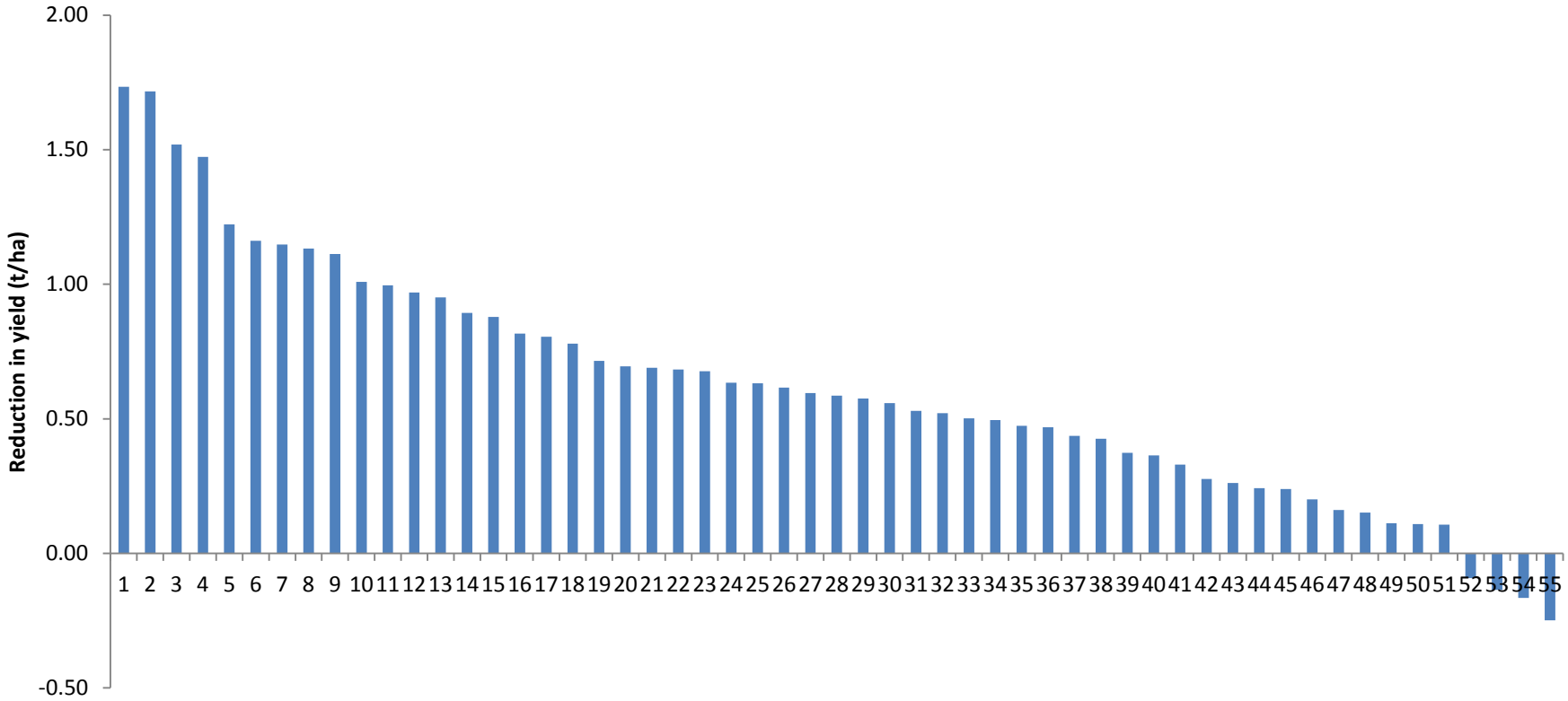

Fig 1. Reduction in yields resulting from leaving chlorothalonil out of the fungicide application in winter wheat. A total of 55 comparisons across 17 trials completed during the 2016 and 2017 growing seasons.

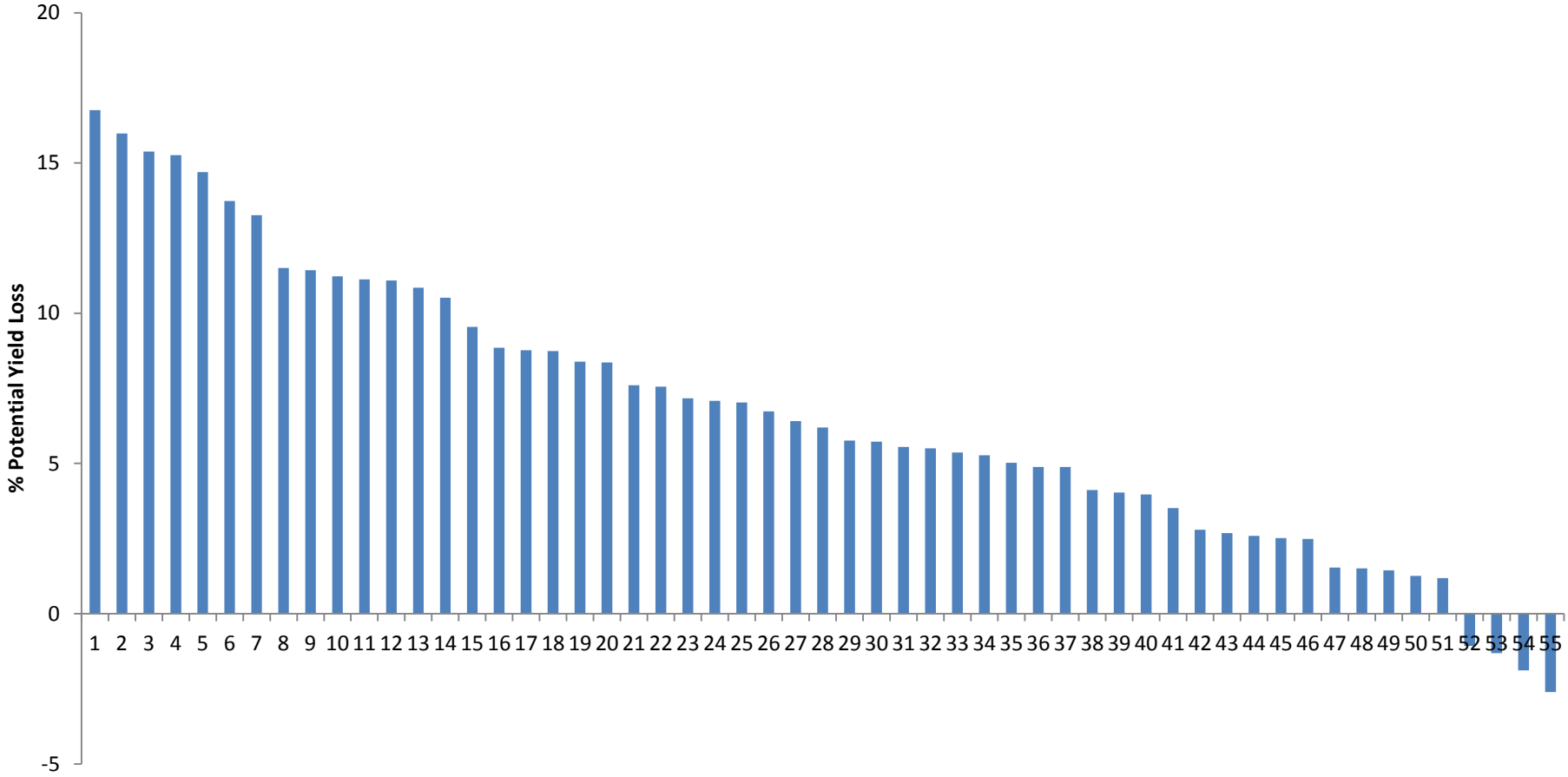

Fig 2. Percentage loss in yield resulting from leaving chlorothalonil from the fungicide application in winter wheat. Potential yield was taken as the yield recorded where chlorothalonil was included.

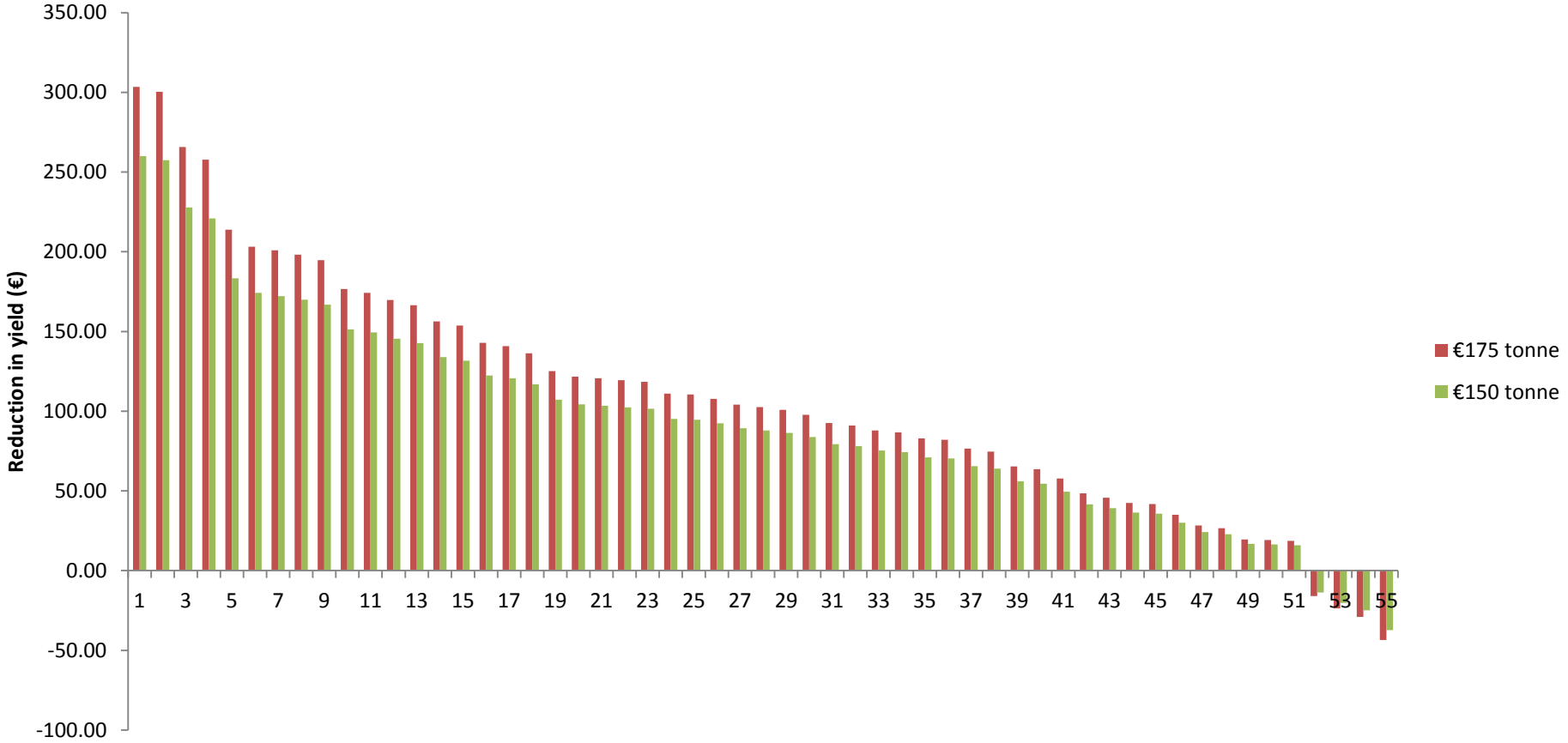

Fig 3. The reduction in output represented as economic value (Euro) based on grain prices of €150 and €175/tonne from leaving chlorothalonil out of the fungicide treatment in winter wheat.

Table 1: Potential yield loss levels in winter wheat and likelihood of occurrence at commercial scale following loss of CTL*

Potential Losses	% Lost	Existing fungicide programme without CTL	Replacement of CTL with folpet	Increased application rates and replacement of CTL with folpet
Mean	6.7	Unlikely as resistance to azole/SDHI increases and impact efficacy	Likely to occur in high disease pressure environments	Likely to occur in high disease pressure environments. Increased resistance will impact efficacy of azole/SDHIs
Median	6.2	As above	As above	As Above
Minimum	-2.6	Extremely unlikely to occur	Extremely unlikely to occur	Extremely unlikely to occur
Maximum	16.8	Likely to occur in high disease pressure environments or where applications delayed	Unlikely to occur	Unlikely to occur
Upper Quartile	10.3	Most likely to occur as resistance to azoles/SDHIs increases and impact efficacy	May occur in high disease pressure environments or where applications delayed	Unlikely to occur
Lower Quartile	3.0	Very unlikely as resistance to azoles/SDHIs increase and impact efficacy	Likely to occur in low to moderate disease pressure environments	Likely to occur on lower pressure sites. Increased resistance will impact efficacy of azoles/SDHIs

*Those scenarios highlighted in yellow represent the most likely outcome taking into account what is most likely to happen at farm level.

16.76% to -2.6% yield loss when chlorthalonil is left of the programme. At an estimated grain price of €150/tonne this represents an average loss of €93.02, but again a range of €303 loss to €37 gain in the case where a benefit from excluding CTL was recorded. The % yield losses were used to calculate six specific % loss scenarios (Table 1). These represent future scenarios if CTL is no longer available. Under all three disease control strategies each % loss scenario (excluding a potential gain as this is not deemed realistic at field scale) results in an increased cost of production per tonne grain is experienced. As might be expected this is greater for less productive crops (Tables 2-4, most likely outcome in each case is highlighted in yellow). Using the average winter wheat yield achieved on Irish farms over the past 8 years (9.7 t/ha) the cost of producing a tonne of wheat (based on the anticipated likely yield loss associated with the loss of chlorothalonil) can be expected to increase by between 8-12%.

These estimations assume moderate disease levels and moderate levels of disease control are maintained by the azoles/SDHIs. The presence of complete resistance to the SDHI fungicides in the Irish *Z. tritici* does place the moderate levels of efficacy currently provided under extreme uncertainty. The loss of an effective multisite is very likely to hasten the selection for these strains.

By applying these potential reductions in yield and associated input costs to the eProfit monitor data from both 2016 and 2017 shows that for the average winter wheat grower the loss of CTL will significantly impact on the net margin achieved from growing a hectare of winter wheat (Fig 4). As expected the impact of these scenarios on net margin will be largely affected by grain price, however averaging across both seasons it can be expected that the net margin for the production of winter wheat will be reduced by over 50%. As it is highly unlikely that the loss of CTL will have similar immediate impacts on wheat yield elsewhere in the EU and an increase in the price of wheat should not be assumed.

Calculations of costs are based on two sources of information:

- Teagasc Costs and Returns. These figures estimates of costs published each year to help tillage growers plan for the season ahead. These figures estimate Gross Margin per hectare/ton = Gross output (Grain and straw) minus material costs including machinery Costs (Contractor) and other variable costs. Fixed costs such as Labour, land rental, interest, and other overheads as not included.

- Teagasc e-Profit monitor. These figures are gathered from the yearly farm outturn from specialised tillage farms. These farms generally achieve higher yields than the national average and tend to have higher margins. Gross margins are calculated in a similar way to the Teagasc Costs and Returns figures. Net margin is calculated for each crop on each farm as follows: Gross Margin minus and overhead costs including land lease, labour, depreciation, professional fees, heat/light/phone, etc. The figures are calculated down to net margin basis.

Table 2: Projected costs (in Euro) of production per tonne of wheat based on Teagasc Crops Costs and Returns 2018– CTL lost but no further change in fungicide programme. Highlighted rows represent the most likely outcome under this disease control strategy

		Yield (t/ha)									National Average[1]
		8.5	9	9.5	10	10.5	11	11.5	12	12.5	9.7
Current cost of production	€1265	149	141	133	127	120	115	110	105	101	130
Predicted cost of production[2]	€1245	146	138	131	125	119	113	108	104	100	128
Potential losses[3]		Projected Cost per tonne of grain (€)									
Mean		157	148	140	133	127	121	116	111	107	138
Median		156	147	140	133	126	121	115	111	106	137
Min[4]		143	135	128	121	116	110	106	101	97	125
Max		176	166	157	150	142	136	130	125	120	154
Upper Quartile		163	154	146	139	132	126	121	116	111	143
Lower Quartile		151	143	135	128	122	117	112	107	103	132

[1]National average based on average yield of 2010-2017.

[2] Cost of production per hectare decreased by €20 to take account of cost associated with CTL

[3] Table 2 for further information and likelihood of occurrence

[4]Extremely unlikely to occur

Table 3: Projected costs (in Euro) of production per tonne of wheat based on Teagasc Crops Costs and Returns 2018 – CTL replaced by folpet. Highlighted rows represents most likely outcome under this disease control strategy. In this instance it will be very dependent on the disease pressure experience. If moderate-high the mean-upper quartile are more likely.

		Yield (t/ha)									National Average[1]
		8.5	9	9.5	10	10.5	11	11.5	12	12.5	9.7
Current cost of production	€1265	149	141	133	127	120	115	110	105	101	130
Predicted cost of production[2]	1272	150	141	134	127	121	116	111	106	102	128
Potential losses[3]		Projected Cost per tonne of grain (€)									
Mean		160	151	143	136	130	124	119	114	109	141
Median		160	151	143	136	129	123	118	113	108	140
Min[4]		146	138	130	124	118	113	108	103	99	128
Max		180	170	161	153	146	139	133	127	122	158
Upper Quartile		167	158	149	142	135	129	123	118	113	146
Lower Quartile		154	146	138	131	125	119	114	109	105	135

[1]National average based on average yield of 2010-2017.

[2] Cost of production per hectare decreased by €20 to take account of cost associated with CTL

[3] Table 2 for further information and likelihood of occurrence

[4]Extremely unlikely to occur

Table 4: Projected costs (in Euro) of production per tonne of wheat based on Teagasc Crops Costs and Returns 2018 – CTL replaced by folpet and increased application rates and additional fungicides added to programme. Highlighted row represents the most likely outcome under this disease control strategy

		Yield (t/ha)									National Average[1]
		8.5	9	9.5	10	10.5	11	11.5	12	12.5	9.7
Current cost of production	€1265	149	141	133	127	120	115	110	105	101	130
Predicted cost of production[2]	€1342	158	149	141	134	128	122	117	112	107	138
Potential losses[3]		Projected Cost per tonne of grain (€)									
Mean[4]		169	160	151	144	137	131	125	120	115	148
Median		168	159	151	143	136	130	124	119	114	147
Min[5]		154	145	138	131	125	119	114	109	105	135
Max		190	179	170	161	154	147	140	134	129	166
Upper Quartile		176	166	157	150	142	136	130	125	120	154
Lower Quartile		163	154	146	138	132	126	120	115	111	143

[1]National average based on average yield of 2010-2017.

[2] Cost of production per hectare decreased by €20 to take account of cost associated with CTL

[3] Table 2 for further information and likelihood of occurrence

[4]The possible outcome will be dependent on disease pressure, however in moderate-high pressure sites a mean potential loss is most likely

[5]Extremely unlikely to occur

Table 5. Projected impact the loss of CTL and alternative control strategies may have on the net margin of winter wheat production based on the average Teagasc eProfit monitor 2016 figures for winter wheat production. Three likely projected impacts on yield presented

Crop:- Winter Wheat				CTL Lost			CTL replaced by folpet			CTL replaced by folpet and increased dose of SDHI/azole		
2016	Average	top 1/3	Top v Average									
Physical												
Total No. hectares	4295											
No. Of Farms	166	55		Max	Upper	Lower	Max	Upper	Lower	Max	Upper	Lower
Tillage Adj. Ha	26	33	+ 7	16.8 % loss	10.3 % loss	3 % loss	16.8 % loss	10.3 % loss	3 % loss	16.8% loss	10.3 % loss	3 % loss
Yield t/Ha	10.3	10.9	+ 0.59	8.61	9.28	10.03	8.61	9.28	10.03	8.61	9.28	10.03
Financial												
Crop Sales €/tonne	€ 148	€ 154	+ 6									
Gross Output /ha	€ 1,698	€ 1,897	+ 199	€ 1,440	€ 1,540	€ 1,652	€ 1,440	€ 1,540	€ 1,652	€ 1,440	€ 1,540	€ 1,652
of which is straw/ha	*€ 163*	*€ 212*	+ 49									
Material Costs/ha	€ 699	€ 665	- 34	679	679	679	705	705	705	776	776	776
Total Machinery Costs/ha	€ 349	€ 326	- 23	349	349	349	349	349	349	349	349	349
of which are contracto/ha	*€ 120*	*€ 40*	- 80									
Other Variable Costs/ha	*€ 19*	*€ 8*	- 11	19	19	19	19	19	19	19	19	19
Gross Margin / Ha	**€ 630**	**€ 898**	**+ 268**									
Total F. Costs / Ha	€ 367	€ 386	+ 19	367	367	367	367	367	367	367	367	367
Net Margin/ha	**€ 263**	**€ 512**	**+ 249**	**€ 23**	**€ 122**	**€ 234**	**-€ 3**	**€ 96**	**€ 208**	**-€ 74**	**€ 25**	**€ 137**
Net Margin (inc DP) /ha	**€ 276**	**€ 520**	**+ 245**									
Key Figures												
Total Costs €/ton	€ 139	€ 127	- 12	€ 164	€ 152	€ 141	€ 167	€ 155	€ 144	€ 176	€ 163	€ 151
Av. Lan Lease Costs/ha	€ 119	€ 117	- 2									

Table 6. Projected impact the loss of CTL and alternative control strategies may have on the net margin of winter wheat production based on the top 1/3 Teagasc eProfit monitor 2016 figures for winter wheat production. Three likely projected impacts on yield presented

Crop:- Winter Wheat				CTL Lost			CTL replaced by folpet			CTL replaced by folpet and increased dose of SDHI/azole		
2016	**Average**	**top 1/3**	**Top v Average**									
Physical												
Total No. hectares	4295											
No. Of Farms	166	55		Max	Upper	Lower	Max	Upper	Lower	Max	Upper	Lower
Tillage Adj. Ha	26	33	+ 7	16.8 % loss	10.3 % loss	3 % loss	6.7 % loss	6.2 % loss	3 % loss	16.8 % loss	10.3 % loss	3 % loss
Yield t/Ha	10.3	10.9	+ 0.59	9.10	9.81	10.61	9.10	9.81	10.61	9.10	9.81	10.61
Financial												
Crop Sales €/tonne	€ 148	€ 154	+ 6									
Gross Output /ha	€ 1,698	€ 1,897	+ 199	€ 1,614	€ 1,724	€ 1,847	€ 1,614	€ 1,724	€ 1,847	€ 1,614	€ 1,724	€ 1,847
of which is straw/ha	*€ 163*	*€ 212*	+ 49									
Material Costs/ha	€ 699	€ 665	- 34	645	645	645	669	669	669	742	742	742
Total Machinery Costs/ha	€ 349	€ 326	- 23	326	326	326	326	326	326	326	326	326
of which are contracto/ha	*€ 120*	*€ 40*	- 80									
Other Variable Costs/ha	*€ 19*	*€ 8*	- 11	8	8	8	8	8	8	8	8	8
Gross Margin / Ha	**€ 630**	**€ 898**	**+ 268**									
Total F. Costs / Ha	€ 367	€ 386	+ 19	386	386	386	386	386	386	386	386	386
Net Margin/ha	**€ 263**	**€ 512**	**+ 249**	**€ 249**	**€ 359**	**€ 482**	**€ 225**	**€ 335**	**€ 458**	**€ 152**	**€ 262**	**€ 385**
Net Margin (inc DP) /ha	**€ 276**	**€ 520**	**+ 245**									
Key Figures												
Total Costs €/ton	€ 139	€ 127	- 12	€ 150	€ 139	€ 129	153	142	131	€161	€ 149	€ 138
Av. Lan Lease Costs/ha	€ 119	€ 117	- 2									

Table 7. Projected impact the loss of CTL and alternative control strategies may have on the net margin of winter wheat production based on the average Teagasc eProfit monitor 2017 figures for winter wheat production. Three likely projected impacts on yield presented

Crop:- Winter Wheat				CTL Lost			CTL replaced by folpet			CTL replaced by folpet and increased dose of SDHI/azole		
2017	**Average**	**top 1/3**	**Top v Average**									
Physical												
Total No. hectares	5324											
No. Of Farms	154	51		Max	Upper	Lower	Max	Upper	Lower	Max	Upper	Lower
Tillage Adj. Ha	35	28	- 6	16.8 % loss	10.3 % loss	3 % loss	16.8 % loss	10.3 % loss	3 % loss	16.8 % loss	10.3 % loss	3 % loss
Yield t/Ha	10.4	11.2	+ 0.72	8.69	9.37	10.13	8.69	9.37	10.13	8.69	9.37	10.13
Financial												
Crop Sales €/tonne	€ 163	€ 164	+ 1									
Gross Output /ha	€ 1,891	€ 2,084	+ 193	1,605	1,716	1,840	1,605	1,716	1,840	1,605	1,716	1,840
of which is straw/ha	*€ 187*	*€ 250*	+ 63									
Material Costs/ha	€ 678	€ 677	- 0	658	658	658	681	681	681	755	755	755
Total Machinery Costs/ha	€ 253	€ 238	- 16	253	253	253	253	253	253	253	253	253
of which are contractor/ha	*€ 137*	*€ 35*	- 103									
Other Variable Costs/ha	*€ 56*	*€ 51*		56	56	56	56	56	56	56	56	56
Gross Margin / Ha	€ 904	€ 1,117	+ 214									
Total F. Costs / Ha	€ 399	€ 260	- 139	399	399	399	399	399	399	399	399	399
Net Margin/ha	**€ 504**	**€ 857**	**+ 353**	**239**	**350**	**474**	**216**	**327**	**451**	**142**	**253**	**377**
Net Margin (inc DP) /ha	€ 514	€ 698	+ 184									
Key Figures												
Total Costs €/ton	€ 133	€ 125	- 8	157	146	135	160	148	137	168	156	144
Av. Lan Lease Costs/ha	€ 164	€ 171	+ 7									

Table 8. Projected impact the loss of CTL and alternative control strategies may have on the net margin of winter wheat production based on the top 1/3 Teagasc eProfit monitor 2017 figures for winter wheat production. Three likely projected impacts on yield presented

Crop:- Winter Wheat				CTL Lost			CTL replaced by folpet			CTL replaced by folpet and increased dose of SDHI/azole		
2017	**Average**	**top 1/3**	**Top v Average**									
Physical												
Total No. hectares	5324											
No. Of Farms	154	51		Max	Upper	Lower	Max	Upper	Lower	Max	Upper	Lower
Tillage Adj. Ha	35	28	- 6	16.8 % loss	10.3 % loss	3% loss	16.8 % loss	10.3 % loss	3% loss	16.8 % loss	10.3 % loss	3 % loss
Yield t/Ha	10.4	11.2	+ 0.72	9.29	10.02	10.83	9.29	10.02	10.83	9.29	10.02	10.83
Financial												
Crop Sales €/tonne	€ 163	€ 164	+ 1									
Gross Output /ha	€ 1,891	€ 2,084	+ 193	1,776	1,895	2,029	1,776	1,895	2,029	1,776	1,895	2,029
of which is straw/ha	*€ 187*	*€ 250*	+ 63									
Material Costs/ha	€ 678	€ 677	- 0	655	655	655	680	680	680	754	754	754
Total Machinery Costs/ha	€ 253	€ 238	- 16	238	238	238	238	238	238	238	238	238
of which are contractor/ha	*€ 137*	*€ 35*	- 103									
Other Variable Costs/ha	*€ 56*	*€ 51*		51	51	51	51	51	51	51	51	51
Gross Margin / Ha	€ 904	€ 1,117	+ 214									
Total F. Costs / Ha	€ 399	€ 260	- 139	260	260	260	260	260	260	260	260	260
Net Margin/ha	**€ 504**	**€ 857**	**+ 353**	**572**	**691**	**825**	**547**	**666**	**800**	**473**	**592**	**726**
Net Margin (inc DP) /ha	€ 514	€ 698	+ 184									
Key Figures												
Total Costs €/ton	€ 133	€ 125	- 8	130	120	111	132	123	113	140	130	120
Av. Lan Lease Costs/ha	€ 164	€ 171	+ 7									

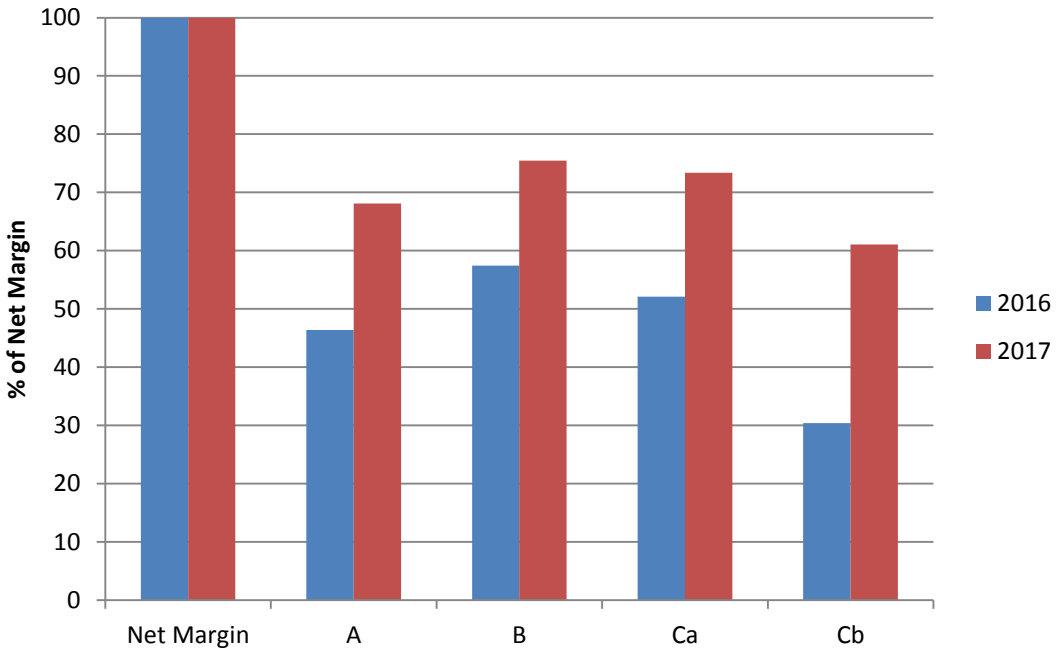

Fig 4. Effect of most likely outcomes of loss of CTL on the net margin of growing an average winter wheat for each of the three proposed control strategies. A = upper quartile loss following no change in current practise; B = mean loss follow replacement of CTL with folpet; Ca = lower quartile loss following replacement of CTL with folpet and increased doses/usage of alternative chemistry; Cb = mean loss following replacement of CTL with folpet and increased doses/usage of alternative chemistry – this is most likely outcome in moderate-high pressure environments. Predicted losses based range of yield losses generated from trial data in 2016 and 2017. Net margin 2016 = €263; Net margin 2017 = €514.

Barley Data Analysis – Ramularia specific

A similar approach was taken to that conducted for the winter wheat review. In both 2016 and 2017 spring and winter barley trials were conducted at Teagasc Oak Park, Co. Carlow and Kildalton, Co. Kilkenny. An additional data set generated in 2018 at Oak Park was also included to represent the most recent emergence and rapid spread of azole and SDHI resistance that have occurred in European Ramularia populations, including the Irish. A total of 9 trials, in which 14 direct comparisons of +/- CTL could be determined were deemed useable. In all cases the CTL product used was Bravo 500 (chlorothalonil 500g/l) and was applied at a rate of 1.0 l/ha. All comparisons were to current market standards (SDHI/azole mixtures) and were applied at 50-60% the recommended label rate. With the exception of one trial all comparisons were made at the final application (GS39-59). In the single trial the comparison was at both the early and late application. Yields (15% moisture) from the plots of the treatments selected and the untreated control plots in each of the 9 trials were extracted and analysed by regression in Genstat to determine the impact of CTL on overall yields. The range in the loss of yield observed, % loss in yield (calculated based on a potential yield where CTL was included), and potential loss in earnings/ha were plotted.

To evaluate how the loss of CTL may impact the economics of growing both spring and winter barley the range of % yield loss was used to calculate the mean, median, maximum, minimum, upper quartile and lower quartile losses and these were used in combination with the costs of production as set out in the Teagasc Crops Costs and Returns 2018. The impacts of the above losses in yield was used to estimate increased cost in production/tonne over a range of predicted yields. To project how these reductions may impact on net margins of production they were applied to the eProfit monitor data for both the average and top 1/3 spring barley producers in both 2016 and 2017. In all analysis two potential disease control scenarios which impact on total costs of production per ha were evaluated. Unlike the winter wheat an increase dosage programme was not evaluated as given the level of resistance that exits to the azoles, the SDHIs and QoI it is not envisaged that this is will be deemed a reliable disease control strategy.

1. Continued fungicide programme – total costs of production per ha reduced by €10/ha to reflect loss of CTL in programme

2. Addition of folpet to fungicide programme – total costs of production per ha increased by €3/ha, taking into account the additional costs above cost of including CTL in a programme.

Potential impacts on barley yields, cost of production and net margins of production

Within the barley dataset available the addition of CTL to barley fungicide programmes specifically for the control of Ramularia had an almost significant impact on yield (P=0.05). There was no significant interaction between CTL inclusion and barley type (spring v winter) and as such the impact on yield is assumed to be similar. Based on this the impact on production and margins are only provided for spring barley. On average the addition of CTL provided an increase of 0.35t/ha, however this ranged from -0.57 t/ha to 1.37 t/ha and its addition was positive in 12 of the 14 comparisons assessed (Fig 5). At a grain price of €140 this represents a loss of €49, with a range of +€80 to -€192 (Fig 6). When compared to potential yield this represents an average yield loss of 4.3% and a range of -6.13% to 15.04% loss (Fig 7). However as the majority of the trials assessed were conducted in a period when resistance to both the SDHIs and azoles was emerging, increased weight should be given to the limited data available from the 2018 trials. Of the four comparisons available from the 2018 trials two showed a response >1t/ha for with the other two showing a response of 0.6t/ha and 0.2 t/h. The differences in these four treatments relates to variety and potentially highlights the need explore varietal resistance as a means of control.

The % yield loss was used to calculate six specific % loss scenarios (Table 6). In light of the issues surrounding Ramularia fungicide resistance an additional "possible" scenario of 10% yield loss has been added. These represent future scenarios if CTL is no longer available. Under both disease control strategies each of these scenarios (excluding a potential gain as this is not deemed realistic) an increased cost of production per tonne grain is experienced. As might be expected this is greater for lower productive crops (Tables 7-8), and most the likely outcome in each case is highlighted in yellow. Using the average spring barley yield achieved on Irish farms over the past 8 years (7.3t/ha) the cost of producing a tonne of spring barley (based on the anticipated likely yield loss associated with the loss of chlorothalonil) can be expected to increase by between 5-11%. The lower estimations assume moderate

levels of varietal resistance will provide moderate levels of control where folpet is used and it is assumed the azoles, QoIs and SDHIs can no longer be relied upon for disease control. If resistance levels in the Irish population are not already at levels that impact control from these fungicides it can be anticipated that the loss of chlorothalonil will greatly hasten the spread of resistance to the point where control cannot be achieved.

By applying these potential reductions in yield and associated input costs to the eProfit monitor data from both 2016 and 2017 shows that for the average spring barley grower the loss of CTL will significantly impact on the net margin achieved from growing a hectare of spring barley (Fig 8). As expected the impact of these scenarios on net margin will be largely affected by grain price, however averaging across both seasons it can be expected that the net margin for the production of spring barley will be reduced by 65%. This is based on the most likely outcome that the replacement of CTL with folpet will only moderately control the disease and possible losses of 10% will occur even on moderately resistant varieties at moderate-high pressure sites. However it is highly unlikely that the loss of CTL will have similar immediate impacts on barley yields elsewhere in the EU and as such an increase in the price of barley should not be assumed.

Calculations of costs are based on two sources of information:

- Teagasc Costs and Returns. These figures estimates of costs published each year to help tillage growers plan for the season ahead. These figures estimate Gross Margin per hectare/ton = Gross output (Grain and straw) minus material costs including machinery Costs (Contractor) and other variable costs. Fixed costs such as Labour, land rental, interest, and other overheads as not included.
- Teagasc e-Profit monitor. These figures are gathered from the yearly farm outturn from specialised tillage farms. These farms generally achieve higher yields than the national average and tend to have higher margins. Gross margins are calculated in a similar way to the Teagasc Costs and Returns figures. Net margin is calculated for each crop on each farm as follows: Gross Margin minus and overhead costs including land lease, labour, depreciation, professional fees, heat/light/phone, etc. The figures are calculated down to net margin basis.

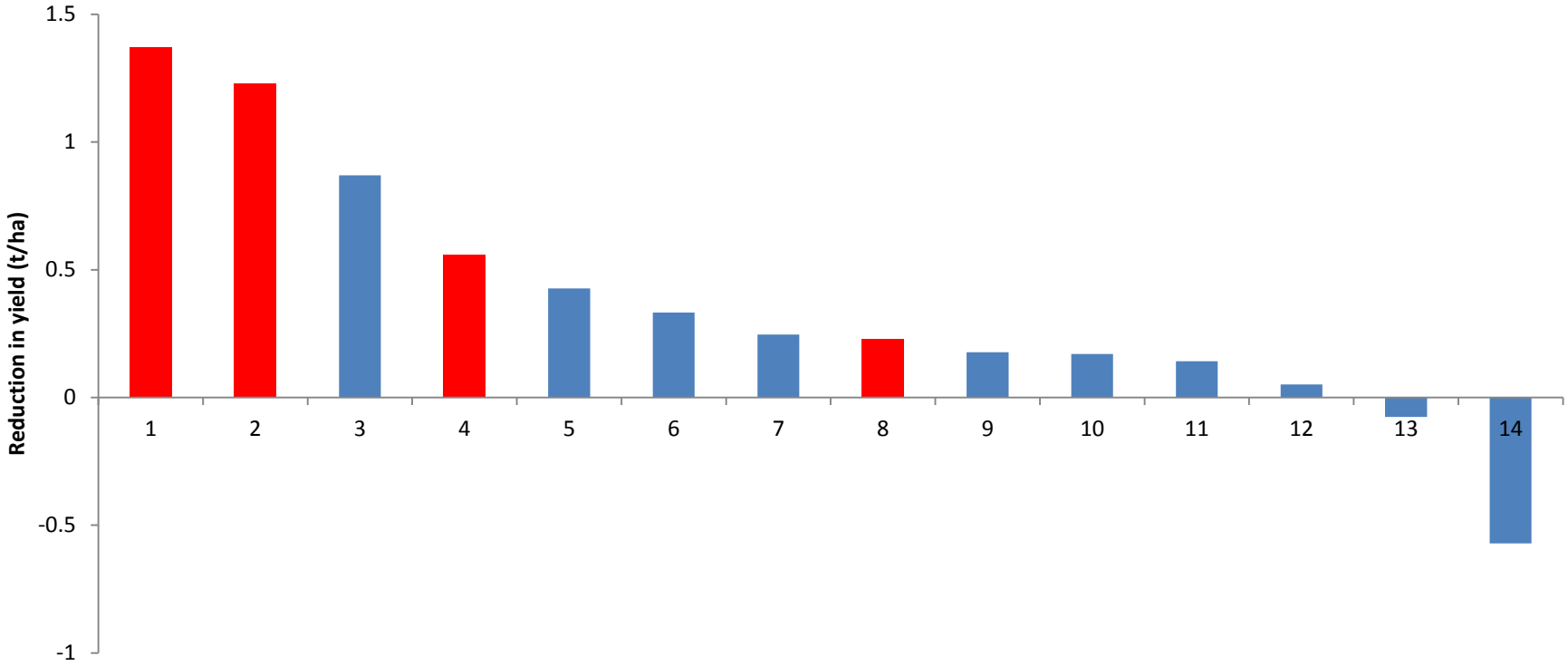

Fig 5. Reduction in yields resulting from leaving chlorothalonil from the fungicide application in barley trials. A total of 14 comparisons across 9 trials completed during the 2016 - 2018 growing seasons. Bars in red represent the data from the 2018 trials.

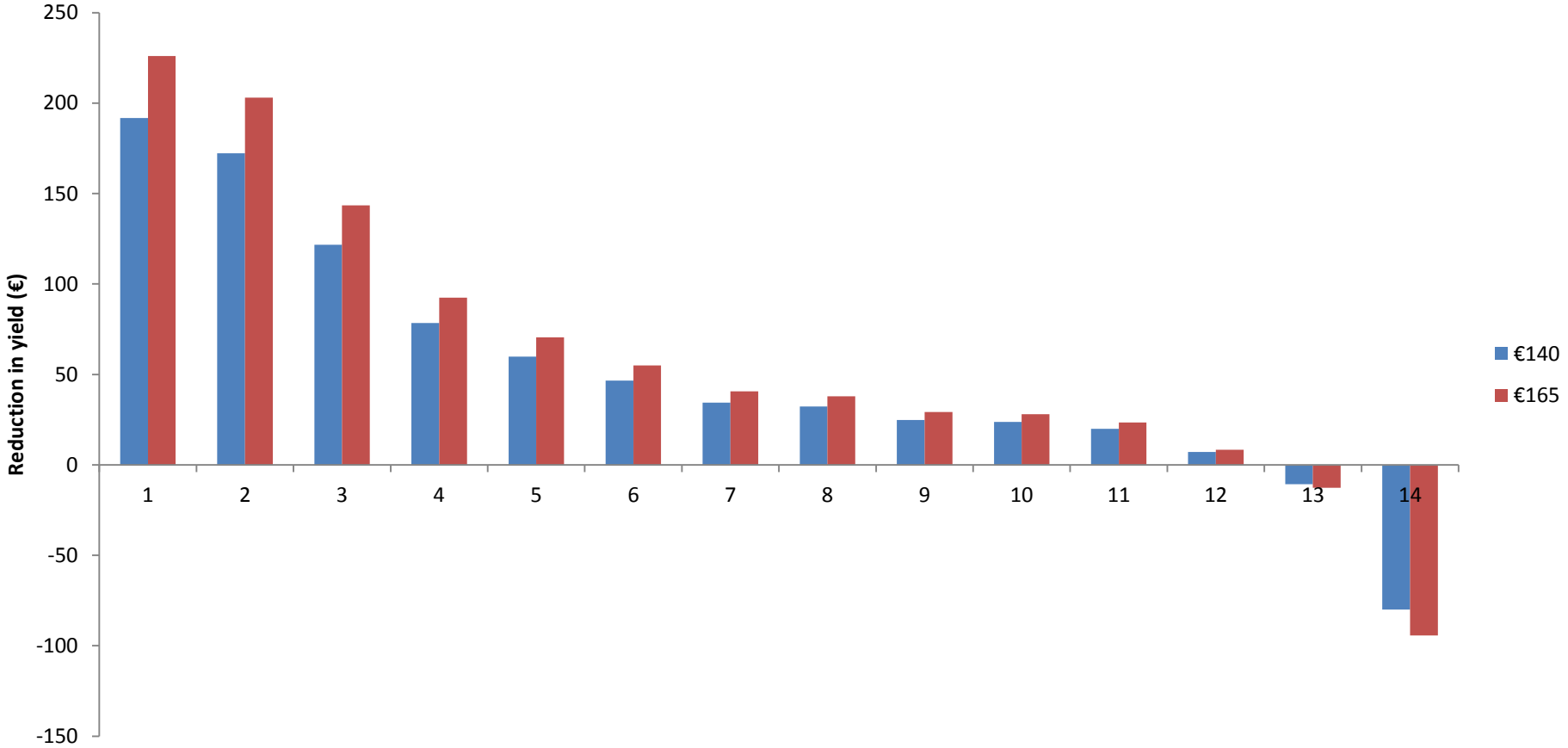

Fig 6. The reduction in yield represented as economic value (Euro) based on grain prices of €140 and €1165 / tonne from leaving chlorothalonil out of the fungicide treatment on barley.

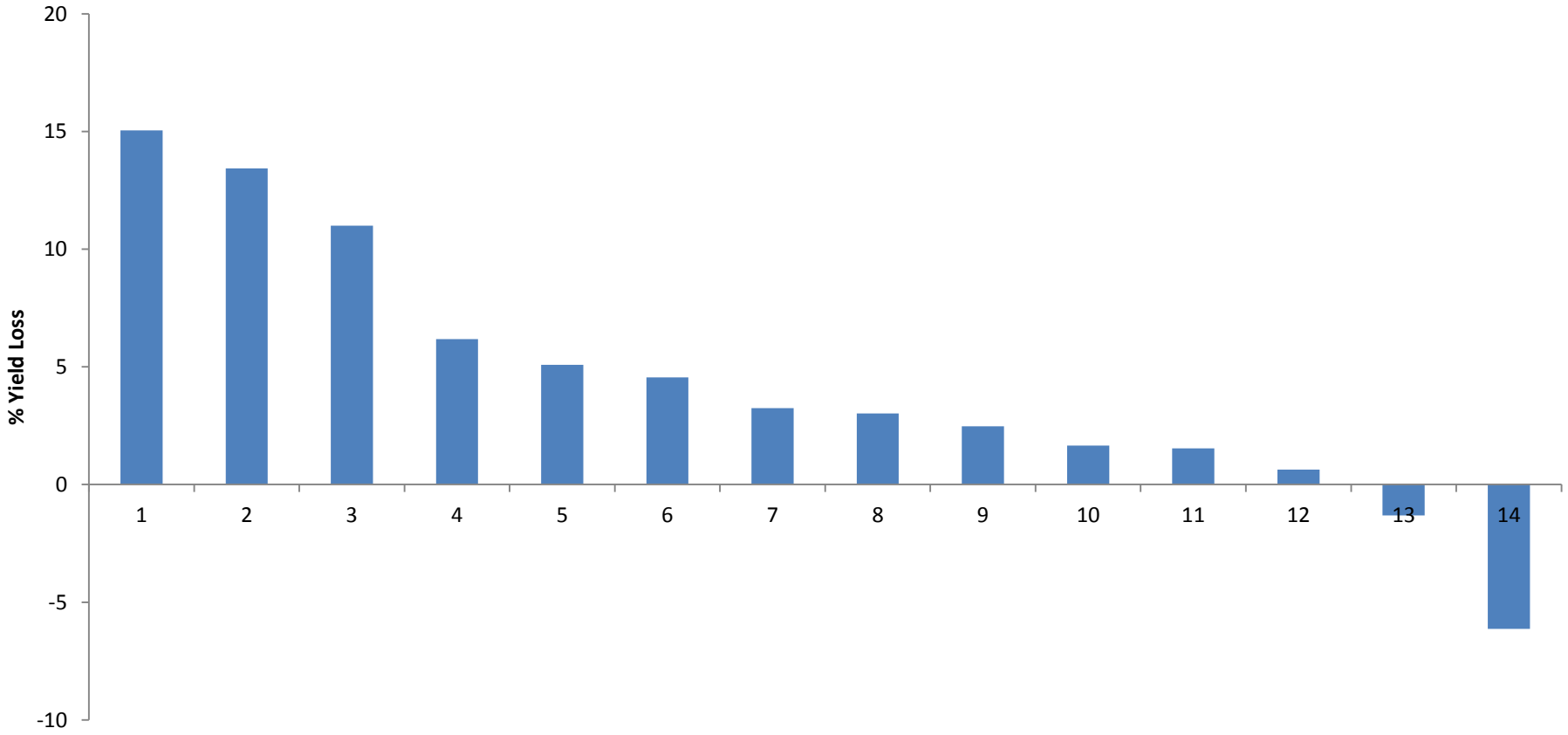

Fig 7. Percentage loss in yield resulting from leaving chlorothalonil from the fungicide application in barley. Potential yield was taken as the yield recorded where chlorothalonil was included.

Table 6: Potential yield loss levels in spring and winter barley and likelihood of occurrence at commercial scale following loss of CTL Predictions based on presence of high levels of resistance to the QoI, azole and SDHI fungicides in Ramularia populations.

Potential Losses	% Lost	No change in fungicide programme	Replacement of CTL with folpet
Mean	4.3	Unlikely as resistance to azole/SDHI increases and impact efficacy	Likely on moderately Ramularia resistant varieties in moderate pressure environments
Median	3.1	As above	As above
Minimum	-6.1	Extremely unlikely to occur	Extremely unlikely to occur
Maximum	15.0	Likely to occur in moderately resistant varieties in high disease pressure environments	Unlikely to occur
Upper Quartile	6.2	Likely on moderately Ramularia resistant varieties in moderate pressure environments	Likely on moderately Ramularia resistant varieties in high pressure environments
Lower Quartile	1.5	Extremely unlikely to occur	Extremely unlikely to occur
Possible*	10	Most likely to occur in moderate disease pressure year	Likely to occur in high pressure years

*Due to rapid changes occurring in sensitivity of Irish Ramularia population the data available may underestimate the potential impacts the loss of CTL may have. As such an additional scenario has been added.

Table 7: Projected costs (in Euro) of production per tonne of spring barley based on Teagasc Crops Costs and Returns 2018– CTL lost but no further change in fungicide programme. Highlighted rows represent the most likely outcome under this disease control strategy

		Yield (t/ha)								National Average[1]
		5.5	6	6.5	7	7.5	8	8.5	9	9.5	7.3
Current cost of production	940	171	157	145	134	125	118	111	104	99	129
Predicted cost of production[2]	930	169	155	143	133	124	116	109	103	98	127
Potential losses[3]		Projected Cost per tonne of grain (€)									
Mean		177	162	150	139	130	121	114	108	102	133
Median		175	160	148	137	128	120	113	107	101	132
Min[4]		159	146	135	125	117	110	103	97	92	120
Max		199	182	168	156	146	137	129	122	115	150
Upper Quartile		180	165	152	142	132	124	117	110	104	136
Lower Quartile		172	157	145	135	126	118	111	105	99	129
Possible		188	172	159	148	138	129	122	115	109	142

[1]National average based on average yield of 2010-2017.

[2] Cost of production per hectare decreased by €10 to take account of cost associated with CTL

[3] Table 6 for further information and likelihood of occurrence

[4]Extremely unlikely to occur

Table 8: Projected costs (in Euro) of production per tonne of spring barley based on Teagasc Crops Costs and Returns 2018– CTL replaced by folpet but no further change in fungicide programme. Highlighted rows represent the most likely outcome under this disease control strategy

		Yield (t/ha)									National Average[1]
		5.5	6	6.5	7	7.5	8	8.5	9	9.5	7.3
Current cost of production	940	171	157	145	134	125	118	111	104	99	129
Predicted cost of production[2]	943	171	157	145	135	126	118	111	105	99	129
Potential losses[3]		Projected Cost per tonne of grain (€)									
Mean		179	164	152	141	131	123	116	110	104	135
Median		177	162	150	139	130	122	115	108	102	133
Min[4]		162	148	137	127	118	111	105	99	94	122
Max		202	185	171	159	148	139	131	123	117	152
Upper Quartile		174	160	147	137	128	120	113	106	101	138
Lower Quartile		183	168	155	144	134	126	118	112	106	131
Possible		191	175	161	150	140	131	123	116	110	144

[1]National average based on average yield of 2010-2017.

[2] Cost of production per hectare increased by €3 to take account of additional cost associated with folpet

[3] Table 6 for further information and likelihood of occurrence

[4]Extremely unlikely to occur

Table 9. Projected impact the loss of CTL and alternative control strategies may have on the net margin of spring barley production based on the average Teagasc eProfit monitor 2016 figures for spring barley production. Three likely projected impacts on yield presented

Crop:- Spring Barley				CTL Lost			CTL replaced by folpet		
2016	**Average**	**top 1/3**	**Top v Average**						
Physical									
Total No. hectares	6684								
No. Of Farms	240	80		Upper	Lower	Possible	Upper	Lower	Possible
Tillage Adj. Ha	28	35	+ 7	5.2 % loss	1.5 % loss	10 % loss	5.2 % loss	1.5 % loss	10 % loss
Yield t/Ha	7.5	7.7	+ 0.26	7.08	7.36	6.73	7.08	7.36	6.73
Financial									
Crop Sales €/tonne	€ 141	€ 146	+ 5						
Gross Output /ha	€ 1,236	€ 1,332	+ 95	€ 1,180	€ 1,219	€ 1,130	€ 1,180	€ 1,219	€ 1,130
of which is straw/ha	*€ 182*	*€ 202*	+ 21						
Material Costs/ha	€ 489	€ 471	- 18	€ 479	€ 479	€ 479	€ 492	€ 492	€ 492
Total Machinery Costs/ha	€ 279	€ 250	- 29	€ 279	€ 279	€ 279	€ 279	€ 279	€ 279
of which are contracto/ha	*€ 80*	*€ 25*	- 54						
Other Variable Costs/ha	*€ 15*	*€ 12*		*€ 15*	*€ 15*	*€ 15*	*€ 15*	*€ 15*	*€ 15*
Gross Margin / Ha	**€ 453**	**€ 599**	**+ 145**						
Total F. Costs / Ha	€ 311	€ 339	+ 28	€ 311	€ 311	€ 311	€ 311	€ 311	€ 311
Net Margin/ha	**€ 143**	**€ 260**	**+ 117**	**€ 97**	**€ 135**	**€ 46**	**€ 84**	**€ 122**	**€ 33**
Net Margin (inc DP) /ha	**€ 167**	**€ 277**	**+ 110**						
Key Figures									
Total Costs €/ton	€ 146	€ 139	- 8	153	147	161	155	149	163
Av. Lan Lease Costs/ha	€ 151	€ 173	+ 22						

Table 10. Projected impact the loss of CTL and alternative control strategies may have on the net margin of spring barley production based on the top 1/3 Teagasc eProfit monitor 2016 figures for spring barley production. Three likely projected impacts on yield presented

Crop:- Spring Barley				CTL Lost			CTL replaced by folpet		
2016	**Average**	**top 1/3**	**Top v Average**						
Physical									
Total No. hectares	6684								
No. Of Farms	240	80		Upper	Lower	Possible	Upper	Lower	Possible
Tillage Adj. Ha	28	35	+ 7	5.2 % loss	1.5 % loss	10 % loss	5.2 % loss	1.5 % loss	10 % loss
Yield t/Ha	7.5	7.7	+ 0.26	7.33	7.61	6.96	7.33	7.61	6.96
Financial									
Crop Sales €/tonne	€ 141	€ 146	+ 5						
Gross Output /ha	€ 1,236	€ 1,332	+ 95	€ 1,273	€ 1,315	€ 1,219	€ 1,273	€ 1,315	€ 1,219
of which is straw/ha	*€ 182*	*€ 202*	+ 21						
Material Costs/ha	€ 489	€ 471	- 18	€ 468	€ 468	€ 468	€ 474	€ 474	€ 474
Total Machinery Costs/ha	€ 279	€ 250	- 29	€ 250	€ 250	€ 250	€ 250	€ 250	€ 250
of which are contracto/ha	*€ 80*	*€ 25*	- 54						
Other Variable Costs/ha	*€ 15*	*€ 12*		*€ 12*	*€ 12*	*€ 12*	*€ 12*	*€ 12*	*€ 12*
Gross Margin / Ha	**€ 453**	**€ 599**	**+ 145**						
Total F. Costs / Ha	€ 311	€ 339	+ 28	€ 339	€ 339	€ 339	€ 339	€ 339	€ 339
Net Margin/ha	**€ 143**	**€ 260**	**+ 117**	**€ 204**	**€ 246**	**€ 150**	**€ 198**	**€ 240**	**€ 144**
Net Margin (inc DP) /ha	**€ 167**	**€ 277**	**+ 110**						
Key Figures									
Total Costs €/ton	€ 146	€ 139	- 8	146	140	154	147	141	155
Av. Lan Lease Costs/ha	€ 151	€ 173	+ 22						

Table 11. Projected impact the loss of CTL and alternative control strategies may have on the net margin of spring barley production based on the top 1/3 Teagasc eProfit monitor 2016 figures for spring barley production. Three likely projected impacts on yield presented

Crop:- Spring Barley				CTL Lost			CTL replaced by folpet		
2016	**Average**	**top 1/3**	**Top v Average**						
Physical									
Total No. hectares	6684								
No. Of Farms	240	80		Upper	Lower	Possible	Upper	Lower	Possible
Tillage Adj. Ha	28	35	+ 7	5.2 % loss	1.5 % loss	10 % loss	5.2 % loss	1.5 % loss	10 % loss
Yield t/Ha	7.5	7.7	+ 0.26	7.33	7.61	6.96	7.33	7.61	6.96
Financial									
Crop Sales €/tonne	€ 141	€ 146	+ 5						
Gross Output /ha	€ 1,236	€ 1,332	+ 95	€ 1,273	€ 1,315	€ 1,219	€ 1,273	€ 1,315	€ 1,219
of which is straw/ha	*€ 182*	*€ 202*	+ 21						
Material Costs/ha	€ 489	€ 471	- 18	€ 468	€ 468	€ 468	€ 474	€ 474	€ 474
Total Machinery Costs/ha	€ 279	€ 250	- 29	€ 250	€ 250	€ 250	€ 250	€ 250	€ 250
of which are contracto/ha	*€ 80*	*€ 25*	- 54						
Other Variable Costs/ha	*€ 15*	*€ 12*		*€ 12*	*€ 12*	*€ 12*	*€ 12*	*€ 12*	*€ 12*
Gross Margin / Ha	**€ 453**	**€ 599**	**+ 145**						
Total F. Costs / Ha	€ 311	€ 339	+ 28	€ 339	€ 339	€ 339	€ 339	€ 339	€ 339
Net Margin/ha	**€ 143**	**€ 260**	**+ 117**	**€ 204**	**€ 246**	**€ 150**	**€ 198**	**€ 240**	**€ 144**
Net Margin (inc DP) /ha	**€ 167**	**€ 277**	**+ 110**						
Key Figures									
Total Costs €/ton	€ 146	€ 139	- 8	146	140	154	147	141	155
Av. Lan Lease Costs/ha	€ 151	€ 173	+ 22						

Table 12. Projected impact the loss of CTL and alternative control strategies may have on the net margin of spring barley production based on the average Teagasc eProfit monitor 2017 figures for spring barley production. Three likely projected impacts on yield presented

Crop:- Spring Barley				CTL Lost			CTL replaced by folpet		
2017	**Average**	**top 1/3**	**Top v Average**						
Physical									
Total No. hectares	5784								
No. Of Farms	208	69		Upper	Lower	Possible	Upper	Lower	Possible
Tillage Adj. Ha	28	36	+ 8	5.2 % loss	1.5 % loss	10 % loss	5.2% loss	1.5 % loss	10 % loss
Yield t/Ha	7.8	8.3	+ 0.55	7.37	7.65	6.99	6.97	7.54	6.63
Financial									
Crop Sales €/tonne	€ 154	€ 158	+ 4						
Gross Output /ha	€ 1,421	€ 1,590	+ 168	€ 1,359	€ 1,403	€ 1,302	€ 1,298	€ 1,385	€ 1,246
of which is straw/ha	*€ 226*	*€ 275*	+ 50						
Material Costs/ha	€ 477	€ 466	- 12	€ 467	€ 467	€ 467	€ 480	€ 480	€ 480
Total Machinery Costs/ha	€ 262	€ 229	- 34	€ 262	€ 262	€ 262	€ 262	€ 262	€ 262
of which are contracto/ha	*€ 145*	*€ 66*	- 79						
Other Variable Costs/ha	*€ 15*	*€ 4*	- 11	*€ 15*	*€ 15*	*€ 15*	*€ 15*	*€ 15*	*€ 15*
Gross Margin / Ha	**€ 667**	**€ 892**	**+ 224**						
Total F. Costs / Ha	€ 352	€ 360	+ 7	€ 352	€ 352	€ 352	€ 352	€ 352	€ 352
Net Margin/ha	**€ 315**	**€ 532**	**+ 217**	**€ 263**	**€ 307**	**€ 206**	**€ 189**	**€ 276**	**€ 137**
Net Margin (inc DP) /ha	**€ 343**	**€ 559**	**+ 217**						
Key Figures									
Total Costs €/ton	€ 142	€ 127	- 15	149	143	157	159	147	167
Av. Lan Lease Costs/ha	€ 175	€ 195	+ 20						

Table 13. Projected impact the loss of CTL and alternative control strategies may have on the net margin of spring barley production based on the top 1/3 Teagasc eProfit monitor 2016 figures for spring barley production. Three likely projected impacts on yield presented

Crop:- Spring Barley				CTL Lost			CTL replaced by folpet		
2017	**Average**	**top 1/3**	**Top v Average**						
Physical									
Total No. hectares	5784								
No. Of Farms	208	69		Upper	Lower	Possible	Upper	Lower	Possible
Tillage Adj. Ha	28	36	+ 8	5.2 % loss	1.5 % loss	10 % loss	5.2 % loss	1.5 % loss	10 % loss
Yield t/Ha	7.8	8.3	+ 0.55	7.89	8.19	7.49	7.89	8.19	7.49
Financial									
Crop Sales €/tonne	€ 154	€ 158	+ 4						
Gross Output /ha	€ 1,421	€ 1,590	+ 168	€ 1,521	€ 1,570	€ 1,458	€ 1,521	€ 1,570	€ 1,458
of which is straw/ha	*€ 226*	*€ 275*	+ 50						
Material Costs/ha	€ 477	€ 466	- 12	€ 456	€ 456	€ 456	€ 469	€ 469	€ 469
Total Machinery Costs/ha	€ 262	€ 229	- 34	€ 229	€ 229	€ 229	€ 229	€ 229	€ 229
of which are contracto/ha	*€ 145*	*€ 66*	- 79						
Other Variable Costs/ha	*€ 15*	*€ 4*	- 11	*€ 4*	*€ 4*	*€ 4*	*€ 4*	*€ 4*	*€ 4*
Gross Margin / Ha	**€ 667**	**€ 892**	**+ 224**						
Total F. Costs / Ha	€ 352	€ 360	+ 7	€ 360	€ 360	€ 360	€ 360	€ 360	€ 360
Net Margin/ha	**€ 315**	**€ 532**	**+ 217**	**€ 473**	**€ 522**	**€ 410**	**€ 460**	**€ 509**	**€ 397**
Net Margin (inc DP) /ha	**€ 343**	**€ 559**	**+ 217**						
Key Figures									
Total Costs €/ton	€ 142	€ 127	- 15	133	128	140	135	129	142
Av. Lan Lease Costs/ha	€ 175	€ 195	+ 20						

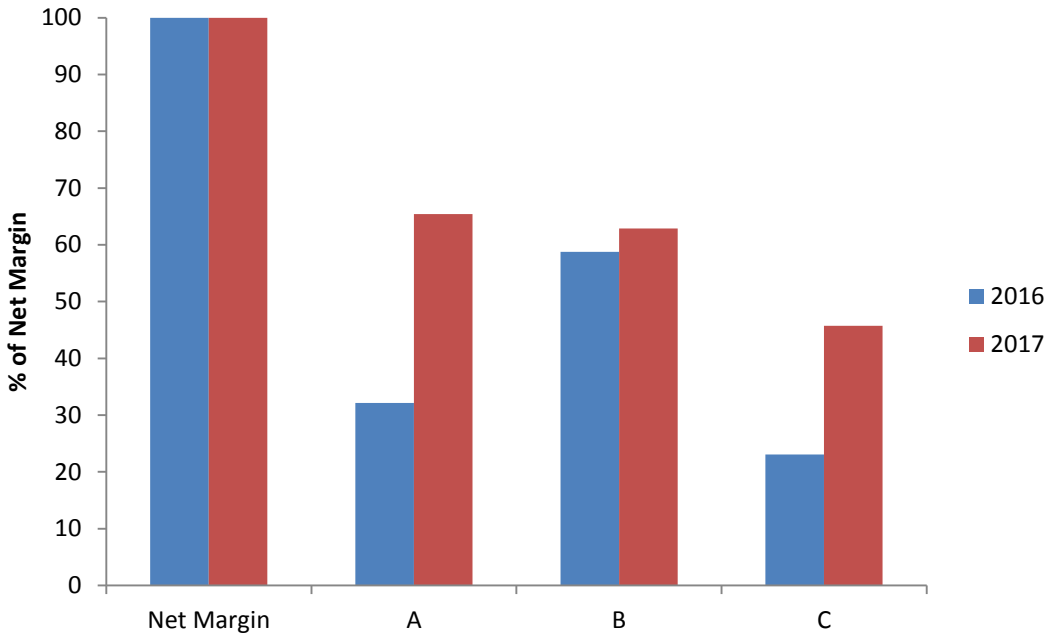

Fig 8. Effect of most likely outcomes of loss of CTL on the net margin of growing an average hectare of spring barley for each of the three proposed control strategies. A = "possible" loss following no change in current practise; B = upper quartile following replacement of CTL with folpet; C = "possible" loss following replacement of CTL with folpet. Predicted losses based range of yield losses generated from trial data in 2016, 2017 and 2018. Net margin 2016 = €143/ha; Net margin 2017 = €315/ha.