Investigate the impact of agronomic practices on mycotoxin levels in oats and analysis of the implications of modifying agronomic practices

Food Standards Agency
Project Report
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Executive Summary

The European Commission (EC) is due to set investigation limits for the fusarium mycotoxins, HT2 and T2, in unprocessed cereals and finished cereal products for human consumption in an EC recommendation. The recommendation proposes the monitoring of HT2 and T2 in unprocessed and finished cereal products by member states in collaboration with food business operators. If samples are identified above the investigation levels then there is a recommendation that food business operators should perform investigations on the factors resulting in these relative high levels and determine the measures to be taken to avoid or reduce such high levels. Guidance levels for HT2 and T2 in feed material and compound feeds are likely to be set as an amendment to Commission Recommendation 2006/576/EC.

The proposed investigation limit for HT2 and T2 combined (HT2+T2) is 1000-1500 µg/kg for unprocessed oats intended for human consumption. Results from observational studies indicate that in each growing season on average, 16% of the UK oat crop exceeds 1000 µg/kg HT2+T2.

This report is an assessment of the impact of various agronomic practices on the level of HT2 and T2 in harvested oats and an economic evaluation of the growers modifying their agronomic practices to reduce the mycotoxins, HT2 and T2, in unprocessed oats. For the purposes of this report and the work done in this project, a limit of 1000 µg/kg HT2+T2 for unprocessed oats was used.

Autumn and spring sown field experiments were conducted over two cropping seasons and two sites to identify the impact of previous crop (oil seed rape and wheat) and cultivation (minimum tillage and ploughing) in full factorial randomised designs. Results were inconclusive as when significant differences did occur they were inconsistent between sowing date, site and/or year. Consequently no recommendation can be made as to the modification of previous crops within oat rotations or cultivation practices to reduce fusarium mycotoxins HT2 and T2 in unprocessed oats and oat products.

Other field studies have also been conducted in recent years to identify the impact of agronomic factors on the mycotoxin concentration of harvested oats. These studies have included an observational study which has identified that oat crops grown in a rotation with a low intensity of cereals have a lower HT2 and T2 content. This study also identified a significantly higher HT2+T2 content in winter compared to spring oats with 17% of winter oat samples exceeding 1000 µg/kg HT2+T2 compared to only 4% of spring oat samples.

Analysis of HT2+T2 in HGCA Recommended List field trials has also identified that higher HT2+T2 occurs in winter compared to spring varieties and that there is a range of HT2+T2 concentrations across different winter oat varieties.

Industry-funded studies on the impact of agronomic factors on the yield and quality of oats were also analysed for HT2+T2. Results from these studies did not identify any significant differences in HT2+T2 concentrations for differences in nitrogen rates, plant growth regulator application and a range of fungicide applications.

Based on the studies to assess the contributions of varying agronomic factors the only adaptation considered practical from the perspective of the oat growers was a varietal change from winter sown oats to spring sown oats.

Rotational changes to reduce intensity and sequence of cereals in the rotation could reduce HT2 and T2 on unprocessed oats. However, the economic impact on the whole rotation is such that it is not considered a realistic or viable option for wide spread adoption.

Robust data is not available for comparison of winter and spring oat crop yields 3. For the purposes of this assessment HGCA Recommended List variety trials were used to provide an indicative yield penalty. The average yield penalty as a result of changing from winter to spring varieties of oats was calculated to be 0.89 tonne/ha for England and 0.97 tonne/ha for Scotland. The average reduction in variable costs of production used in this assessment was taken as £36 per hectare based on standard budgeting data for oats with a variable cost of £299/ha for winter oats and £263/ha for spring oats (Redman 2011).

Based on the assumption that oats for human consumption have an average value of £140 per tonne, the economic consequence of the proposed change in agronomy indicates that a price increase would be required to achieve gross margins from spring sown oats equivalent to that currently expected for winter sown oats. The break-even price increase is in the order of £18.00 per tonne or 12.9%. The breakeven price required in Scotland is less than that in England due to the better average yield achieved in Scotland. This may however be mitigated if the frequency of additional drying costs need to be changed to compensate for weather expectations in Scotland as compared to England. An incentive price will be required to achieve change.

The gross margin for winter varieties of oats indicates that winter varieties are competitive with alternative combinable crops within an arable rotation. At current prices, changing to spring varieties of oats in the rotation would result in gross margin performance about 20% below that achieved by alternative crops which could be substituted in to the rotation. The expectation is that farmers currently growing winter varieties of oats will change to alternative crops rather than change to spring varieties.

Expectations, based on observational studies, are that, of the current winter varieties 17% of production is likely to exceed 1000 µg/kg HT2+T2. This compares to a 4% exceedance rate for spring varieties. The lack of open spot market for oats means that crops failing a HT2 and T2 limit are most likely to be sold locally to livestock farmers with on farm processing facilities. Despite the risk of 17% failure for winter sown varieties, the price penalty for rejected oats needs to be at least 55% reduction before spring oats become a competitive option.

The expectation is that many producers currently producing winter oats will continue to do so rather than change to spring varieties, accepting the risk of price penalty on 17% of product. If a change in crop rotation is made, it will be away from oats to alternative combinable crops.

At current prices implementation of a 1000 µg/kg HT2+T2 limit would reduce the supply of oats available for human consumption. Without detailed survey data it is difficult to predict the shortfall, but with the combination of 17% and 4% failure to meet the limit, yield penalties should some producers switch to spring varieties, competition from alternative combinable crops and no apparent reason for new producers to enter this supply chain, a reduction in supply in the order of at least 20% should be contemplated.

While oats are grown extensively across the European Union, imports of oats to meet the specification for human consumption are not considered to be a solution due to the combination of poor sample quality and mycotoxin levels across the EU. There will not be a surplus of grains available for export to the UK. Local sourcing is also a feature of niche and value added processing which would preclude the use of imported oats.

1. Introduction

The European Commission is currently considering setting investigation limits for HT2 and T2 in cereals and cereal products intended for human consumption and guideline limits for HT2 and T2 in feed material and compound feeds. Results from a previous FSA/HGCA-funded project "Investigation of fusarium mycotoxins in UK barley and oat production" (Edwards 2007) identified high concentrations of HT2 and T2 in unprocessed oats. Analysis of agronomic factors identified a role of several factors as important parameters, but due to the unbalanced nature of the dataset the role of these factors could not be accurately measured. This project has four distinct tasks:

a) Evaluation of the role of previous crop and cultivation in the HT2 and T2 content of harvested oats using replicated field trials
b) Review of other data relating to the impact of agronomic factors on the HT2+T2 content of oats at harvest
c) Propose one or more modifications to oat production which will reduce the HT2 and T2 content of harvested oats
d) Perform a risk-based analysis of the proposed modifications to oat agronomy, including economic implications

For the purpose of this study a limit of 1000 µg/kg HT2+T2 was considered in the assessment of the economic implications.

2. Background

HT2 and T2 are two closely related type A trichothecenes produced by several *Fusarium* species. These mycotoxins have a high cellular toxicity and as T2 is readily metabolised into HT2 after ingestion they have equivalent mammalian toxicity (Anon 2001). In a recent review of available data the EFSA Contam panel (EFSA Panel on Contaminants in the Food Chain) calculated a TDI of 0.1 µg/kg body weight/day (EFSA Panel on Contaminants in the Food Chain (CONTAM) 2011). The European Commission set legislation for several fusarium mycotoxins in 2006 including deoxynivalenol and zearalenone. Investigation limits for HT2 and T2 are currently under discussion. Proposed investigation limits for unprocessed oats are 1000-1500 µg/kg HT2+T2 and 50-75 µg/kg HT2+T2 for finished oat products for human consumption. Guidance limits for feed material and compound feeds are also under discussion. Current proposed limits are 3000 µg/kg HT2+T2 for oats and oat products and 250 µg/kg for compound feed for pigs, poultry and fish.

F. langsethiae has recently been implicated in the high levels of HT2 and T2 reported in European cereals (Edwards et al. 2009). This species is newly identified (Torp and Nirenberg 2004) and appears to be a weak pathogen although little is known of its epidemiology and to date attempts to mimic infection using artificial inoculation have failed (Imathiu 2008; Divon et al. 2011),. There have been extensive studies of the impact of agronomy on the development of fusarium head blight of wheat and the resulting contamination of deoxynivalenol in grain (Edwards 2004; Schaafsma et al. 2005), but very little is known regarding the impact of agronomy for HT2 and T2 contamination of oats.

Previous observational studies of UK oats have identified relatively high concentrations of HT2 and T2 in UK oats (Edwards 2009). The mean and maximum combined concentration of HT2 and T2 (HT2+T2) was 570 and 9990 µg/kg. There was a five-fold higher concentration of HT2+T2 in conventional compared to organic samples. For conventional oats from 2002 to 2008, the number of samples exceeding 1000 µg/kg has averaged 16% and has varied between seasons from 1-30%.

Analysis of the agronomic inputs identified several factors which had an impact on the HT2+T2 concentration (Edwards 2007). These included variety, previous crop, cultivation, fungicide use and practice (organic or conventional). The data formed two discreet clusters of organic and conventional samples, as a consequence of the multicollinearity[1] within the dataset it was not possible to provide valid results about the individual agronomic factors identified. The agronomic factor; practice (organic or conventional) was highly significant when placed at the front of the model and was still significant when placed at the end of the model, after the other confounding agronomic factors. This indicated that there were one or more other factors not included within the model that, in part, explained for the difference between organic and conventional oats.

The impact of previous crop and cultivation can be studied using field experiments where all other agronomic factors are standardised. However, due to the logistical issues of the area of ground required to operate machinery for cultivation, sowing, application of agronomic inputs and harvesting of agricultural crops these agronomic factors cannot be studied in standard field experiments of replicated small plots in randomised blocks. However, both the production of previous crops and cultivations can be replicated using a strip plot design.

[1] two or more predictor variables in a multiple regression model are highly correlated

3. Previous crop and cultivation field experiments

3.1 Materials and Methods

Field experiments were performed at two sites which represent major oat growing regions of the UK (East of Scotland and West of England) each year for two years.

Experiments were performed at Glenrothes, Fife in the East of Scotland and Newport, Shropshire in the West of England. Both regions are important growing regions for oats for human consumption in the UK due to the location of mills for processing oats in these regions. The site at Glenrothes was managed by Scottish Agronomy and the site at Newport was managed by the Crop and Environment Research Centre at Harper Adams University College.

Experiments were performed over two years. In the first growing season strips of previous crops were cultivated. Previous crops were selected as the most common cereal and non-cereal previous crops for oat production. These were winter wheat and winter oils seed rape (OSR). In the second growing season the winter and spring oat crops were cultivated. The first experiment was set up in the 2008/2009 growing season and the second was set up in the 2009/2010 growing season. As a consequence the oats from the first and second experiments were harvested in 2010 and 2011 respectively.

Trials of winter (cultivar Gerald) and spring (cultivar Firth) oats were designed as factorial experiments to test the importance of previous crop (wheat and oil seed rape) and cultivation (ploughing and minimum tillage) as a two-dimensional strip plot design with four replicated strips of two levels (8 strips x 8 strips, total of 64 plots per trial) (Figure 1 and 2). The experiments contained replicated strips of wheat and oil seed rape (12 m wide) to be grown one year in advance for each experiment. The land was then cultivated in replicated strips of ploughed and minimum tillage (12 m wide), perpendicular to the strips of previous crops. Oats were drilled across the whole trial area and managed using standard farm agronomy for oats for human consumption. At harvest, discard areas were removed around each plot (ca. 2 m wide border) and a central region (ca. 20 m^2) of each plot was harvested and retained for quality analysis. The following components were quantified from each plot:

1. Yield (tonne/ha at 15% moisture content)
2. Kernel content (% weight of groats)
3. Specific weight (kg/hl)
4. Screenings (%<2mm)
5. Weed seeds
6. Admixture (other cereals)
7. HT2 and T2 content (µg/kg)

Yield was determined at harvest and adjusted to tonne/ha at a fixed moisture content of 15%. Quality parameters were quantified by GrainCo Scotland, Turriff using industry standard methods for oat quality. HT2 and T2 was estimated using Ridascreen T2 assay kits (R-Biopharm AG, Darmstadt, Germany) as previously published (Edwards et al. 2012). The kit was used according to the manufacturer's instructions except the combined concentration of HT2+T2 was estimated based on the known ratio of HT2 to T2 in UK oats (3.295) (Edwards 2009) and the known cross-reaction of the Ridascreen® T2 antibody to HT2 (11%), the combined concentrations of the HT2+T2 were estimated by multiplying the ELISA result by 3.152. The ELISA estimation was validated by comparing results to previously quantified oat samples which were analysed by a UKAS-accredited GC-MS method. Results showed that the ELISA kit gave near equivalent values as determined by the GC-MS method in the range of 50-5000 µg/kg (Edwards et al. 2012).

The original validation comparing the ELISA estimate to the concentration of HT2+T2 determined by GC/MS showed a relationship close to a 1:1 ratio and when forced through the origin gave an equation of ELISA value = (GC/MS value)1.07 with the equation accounting for 90% of the variance. For quality assurance purposes the minimum, median and maximum HT2+T2 concentration samples from each experiment (n=24) were also analysed by a UKAS accredited method at Campden BRI. The trichothecenes HT2 and T2 were analysed by LC/MS/MS. Spiked samples were included in the analysis to determine extraction recovery. The method had acceptable recovery range for each trichothecene of 60-120% and results were corrected for recovery. The method has expanded measurements of uncertainty of 41% for T2 and 17% for HT2.

The regression analysis of the ELISA estimate to the concentration of HT2+T2 determined by LC/MS/MS method was very similar to the original validation with an equation of ELISA value = (LC/MS/MS value)1.24 with the equation accounting for 94% of the variance. The coefficient of variance indicated a strong relationship between the two methods but the ELISA appeared to give an overestimate of HT2+T2 of ca. 24%. This is similar to the overestimate determined during the original validation of 7% using a GC/MS UKAS accredited method. This may be a result of the ELISA cross-reacting with other close relatives of T2, such as T2 triol and tetraol, which commonly occur as co-contaminants with T2 (Gottschalk et al. 2007).

3.2 Statistical analysis

All data was analysed for each experiment individually using residual maximum likelihood (REML) analysis with a regular grid spatial model (Genstat, v14, VSN International Ltd). Residual plots were observed and data were log transformed before re-analysis if residual plots were not normally distributed. Where a significant interaction occurred, the Least Significant Difference (LSD) at the 5% significance level was used to identify differences between treatments.

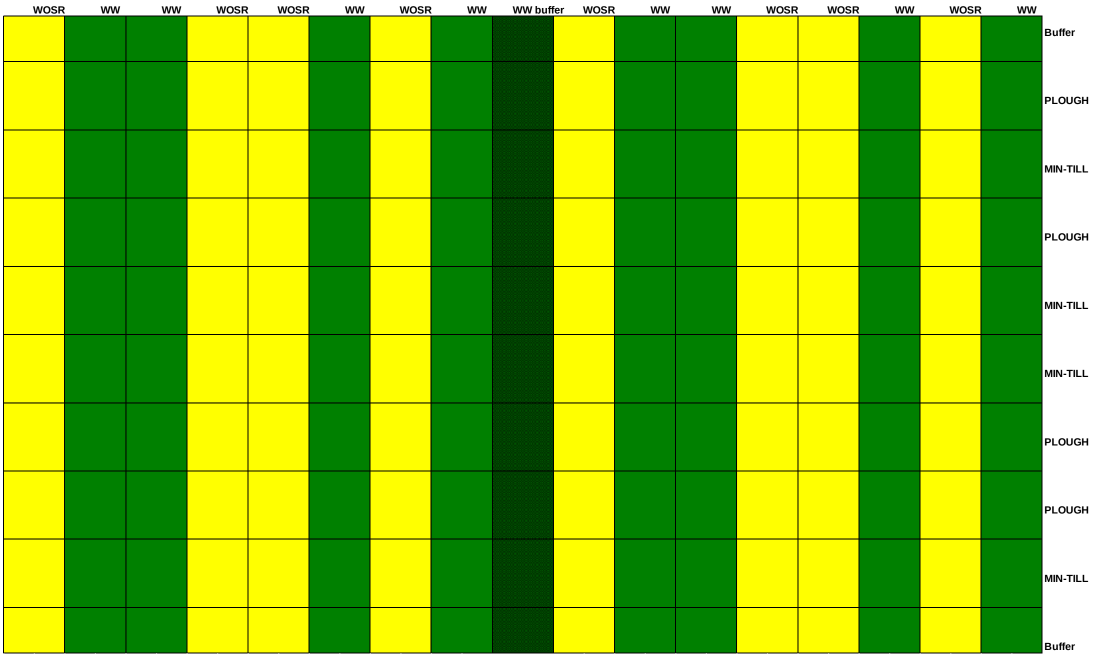


Figure 1: Example of randomised strip/strip design for previous crop (WW, winter wheat; WOSR, winter oil seed rape) in columns and cultivation (plough and min-tillage) in rows. Each square represents an experimental plot (12x12 m). Two adjacent experiments of winter (variety Gerald) and spring (variety Firth) sown oats at Glenrothes in the 2009/2010 season.

Figure 2: Aerial photograph of field experiments detailed in Figure 1 during production of previous crops in randomised strips (May 2009)

3.3 Results

3.3.1 Mycotoxin content

There were significant ($p<0.05$) differences between the HT2+T2 concentration of harvested oat samples in five of the eight experiments. Most differences between HT2+T2 treatment means were not significant when mycotoxins levels were low (grand mean <200 µg/kg HT2+T2)

In the winter sown experiments at Scottish Agronomy the levels of HT2+T2 were high at both harvests (2010 and 2011) with overall means of 1253 and 1076 µg/kg respectively (Figure 3A). Both years had significant differences between the HT2+T2 concentration of oats grown after wheat and OSR ($p=0.031$ and 0.032 respectively). There was no significant effect of cultivation or interaction between previous crop and cultivation ($p>0.05$). However the difference between HT2+T2 content in oats after different previous crops was the opposite in the two years with an 18% higher mycotoxin content in oats after OSR in 2010 and a 14% higher mycotoxin content in oat samples after wheat in 2011.

In the spring sown experiments at Scottish Agronomy the overall mean HT2+T2 concentration was 348 and 105 µg/kg in 2010 and 2011 respectively. There was a significant interaction in 2010 ($p=0.025$) with significantly higher HT2+T2 in oats after OSR and min-till compared to oats grown after OSR and ploughed. Intermediate concentrations occurred in oats grown after wheat irrespective of the method of cultivation. For the oats following OSR, samples following min-till had HT2+T2 concentrations 31% higher than those following ploughing in 2010. There was no significant difference between treatments in the spring sown 2011 trial at Scottish Agronomy.

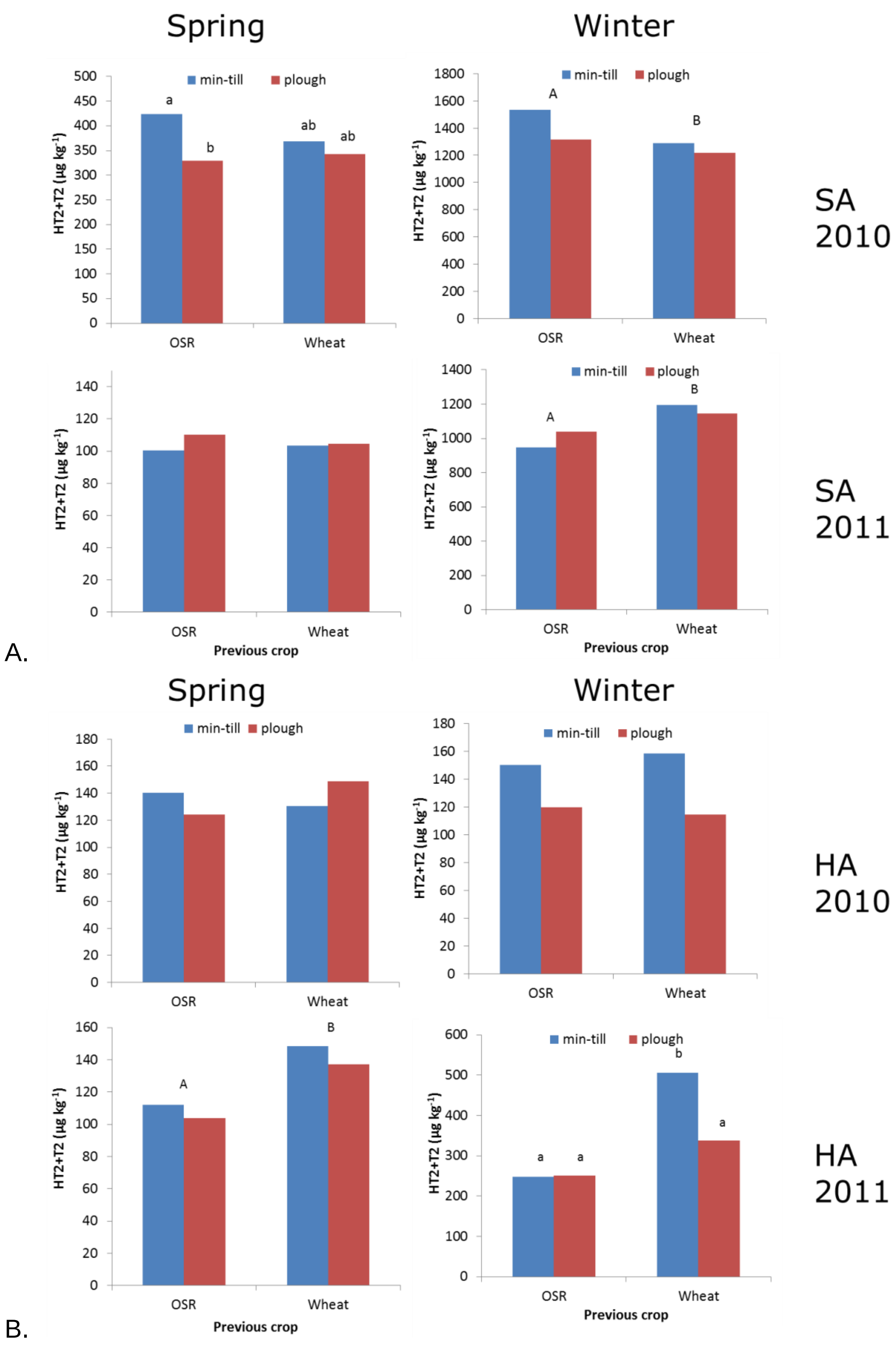


Figure 3: Predicted mean HT2+T2 concentration (µg/kg) for each treatment. A. Scottish Agronomy (SA) experiments; B. Harper Adams (HA) experiments. Capital letters show significantly different main factors, lower case show significant interactions.

The mycotoxin content of oats samples from Harper Adams experiments were generally lower than seen at Scottish Agronomy (Figure 3B). The mean concentrations of the winter and spring sown experiments in 2010 were 136 and 135 µg/kg respectively. There was no significant difference (p>0.05) between treatments in either of these experiments. In 2011, both winter and spring sown experiments at Harper Adams had significant differences. In the spring sown experiment the mean HT2+T2 concentration of oats grown after wheat was significantly (<0.001) higher than that of oats grown after OSR. The difference was 32% although the overall mean was still low at 124 µg/kg. For winter sown oats harvested at Harper Adams in 2011 there was a significant interaction (p<0.001) with oats grown after wheat and min-till having a mean HT2+T2 concentration higher than all other treatments and 50% higher than oats grown after wheat and ploughing.

Although significant differences were detected across all the experiments, they were mainly small (ca. 30%) and differences were not consistent between sites and years.

3.3.2 Yield

For Scottish Agronomy sites, all experiments yielded well (7.8 to 10.2 tonne/ha overall predicted means). There was a consistent significant (p<0.05) higher yield for oats following OSR compared to following wheat as previous crop (Figure 4A). Cultivation was significant in one trial only (Spring sown, 2010 harvest), with oats after ploughing, yielding higher compared to oats after minimum tillage.

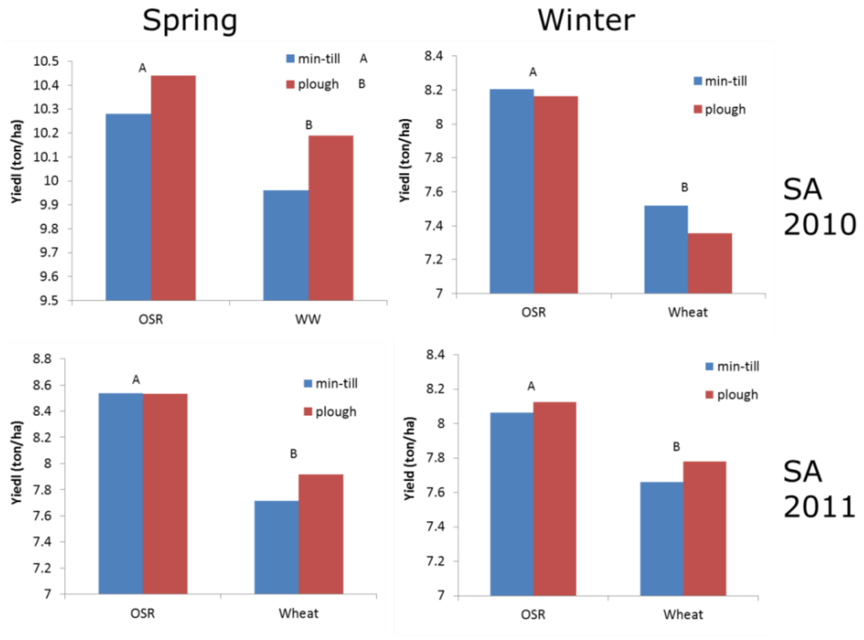
For Harper Adams sites, lower yields occurred in both years (Figure 4B) compared to the Scottish Agronomy experiments (4.2 to 7.9 tonne/ha overall predicted means). This can be attributed to drought-stress during these growing seasons. Drought stress was observed to be worse in 2010 when the crop was grown on free-draining shallow sandy soil. No significant (p>0.05) differences in yield occurred in any experiment at Harper Adams.

3.3.3 Quality Parameters

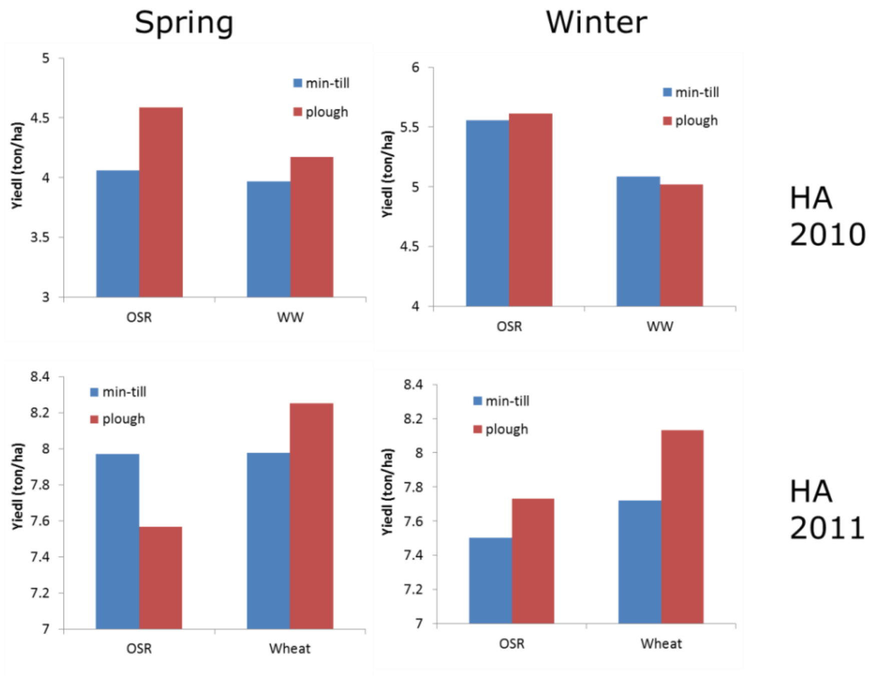
Oats are required to meet minimum quality parameters for milling for human consumption. These parameters impact on the mill efficiency and final product quality. The quality parameters set varies between mills and samples close to, but below set criteria are usually penalised rather than rejected, whereas premiums are not usually paid for higher than expected value for quality parameters. It is therefore important that oats meet the minimum quality parameters set but there is no economic benefit to the grower of having higher values once a quality threshold is met.

Quality parameters vary depending on the mills equipment and range of products.
A typical trade requirement is:

- Specific weight > 50 kg/hl
- Moisture content < 15%
- Screenings (<2mm) < 6% w/w
- Admixture (wheat, barley, straw) <2% w/w
- Weed seeds <40 seeds /100 g



A.



B.

Figure 4: Predicted mean yield (tonne/ha) for each treatment. A. Scottish Agronomy (SA) experiments; B. Harper Adams (HA) experiments. Capital letters show significantly different main factors, lower case show significant interactions.

Overall mean quality parameters were all above or close to limits and there were few significant differences. When differences were significant the actual differences were small and would not result in an economic shift in the risk of failing to meet quality specifications.

The one exception to this observation was the large differences observed for weed and wheat seed counts in winter oat experiments. Both these counts were unacceptably high after previous crop wheat and min-till cultivations with exceeded limits in some plots. This was not seen in spring crops as both wheat volunteers from the previous crop and weeds can be controlled by herbicides before spring sowing. The difference observed was not analysed by REML as residuals were not normally distributed and transformation failed to normalise the residuals. An example is shown in Figure 5. As can be seen based on the mean and SEM, there is a significantly higher level of wheat seed in winter oat crops following a previous crop of wheat and min-till cultivation with a mean wheat seed count of 30 seeds per 100 g of oat sample. This count would be equivalent to ca. 1.5% with several individual plot samples exceeding the quality threshold of 2% admixture.

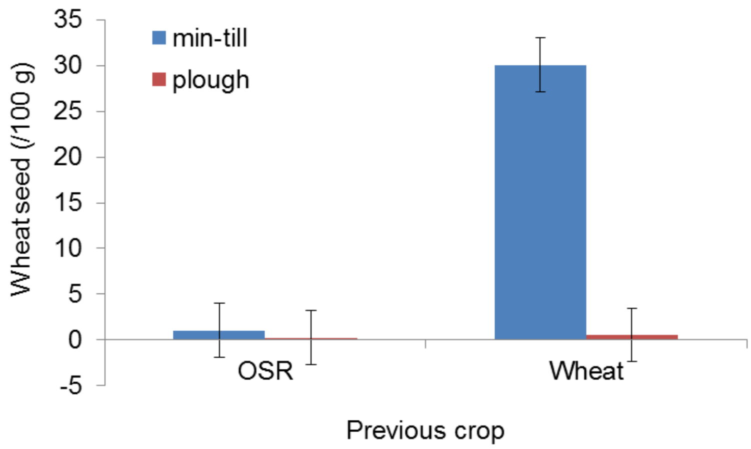


Figure 5: Mean wheat seed count (number/100 g) in oat grain samples at harvest (2011) for the winter sown experiment at Harper Adams. Error bars indicate the SEM (2.9 seeds/100g)

4. Results from other studies on the impact of agronomy on the HT2 and T2 concentration in oats

4.1 HGCA project RD-2007-3332

This was an observational study where ca. 100 oat samples were collected at harvest each year (2006-2008). HT2+T2 content was modelled against the associated agronomy data for each sample. Full details of this project will be published shortly (Edwards in press). Where equivalent agronomic data was available then models included data from a previous four year data set (2002-2005).

Although results indicated a significant interaction (P=0.027) between previous crop and cultivation there was a large degree of variability for several factor levels as seen by the 95% confidence intervals (Figure 6). The only factor level combination to be significantly lower than others was for oat samples grown after two non-cereal crops and ploughed. This factor level was relatively uncommon and was largely made up of samples after grass which would have been out of an arable rotation for typically 4-5 years. Results suggest that inversion ploughing reduces the inoculum resulting in lower levels on the oat crop. There was also an indication that ploughing 2 years after a cereal crop may bring inoculum back to the surface resulting in higher incidence of HT2 and T2 on oats.

Although previous crops beyond two years were not significant this was tested further by including two other variations of previous crop. These were cereal intensity (number of cereal crops in the last four years) (Figure 7) and cereal sequence (number of last four years in continuous cereal production) (Figure 8). Both factors were highly significant ($p<0.001$). For cereal intensity a value of zero signifies a crop which was not preceded by a cereal for at least four years. For cereal sequence a value of zero signifies a crop which was not preceded by a cereal for at least one year. For both factors a value of greater than three indicates the crop was preceded by cereals for at least four years.

Results indicate that there is a positive relationship between cereal intensity or cereal sequence and HT2+T2 content of oats: as cereal intensity (or sequence) increase HT2+T2 content also increases.

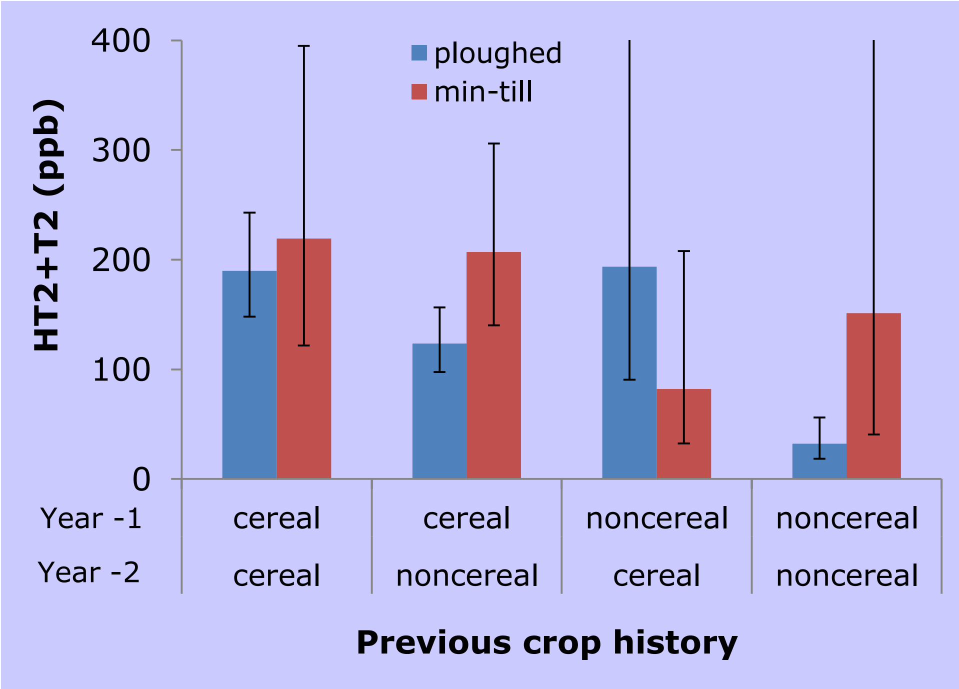


Figure 6: Predicted mean HT2+T2 content for oats grown after different previous crops and cultivation (HGCA data)

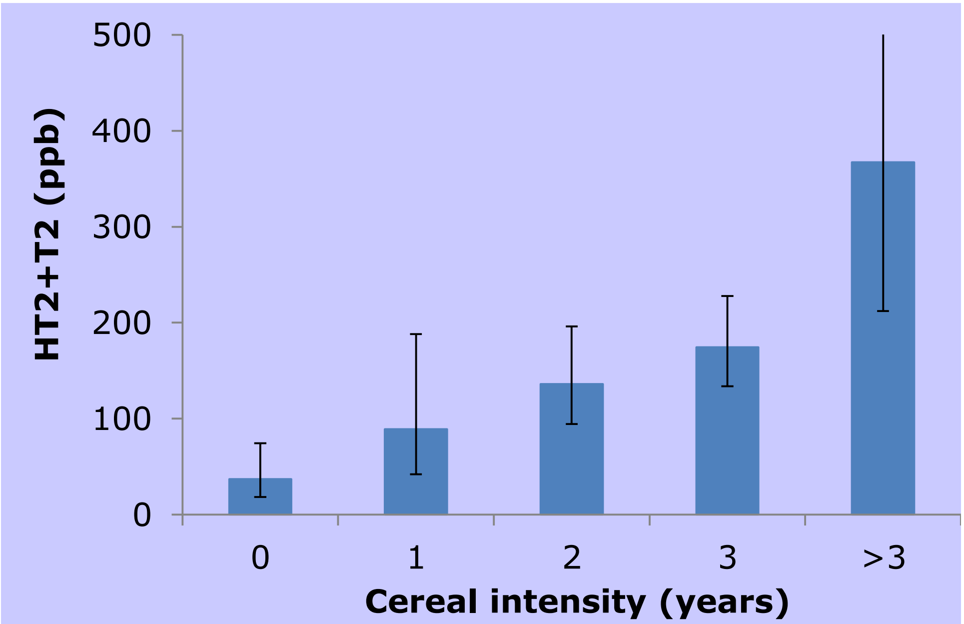


Figure 7: Predicted mean HT2+T2 content of oats classified by the number of cereal crops grown in the previous four years (HGCA data)

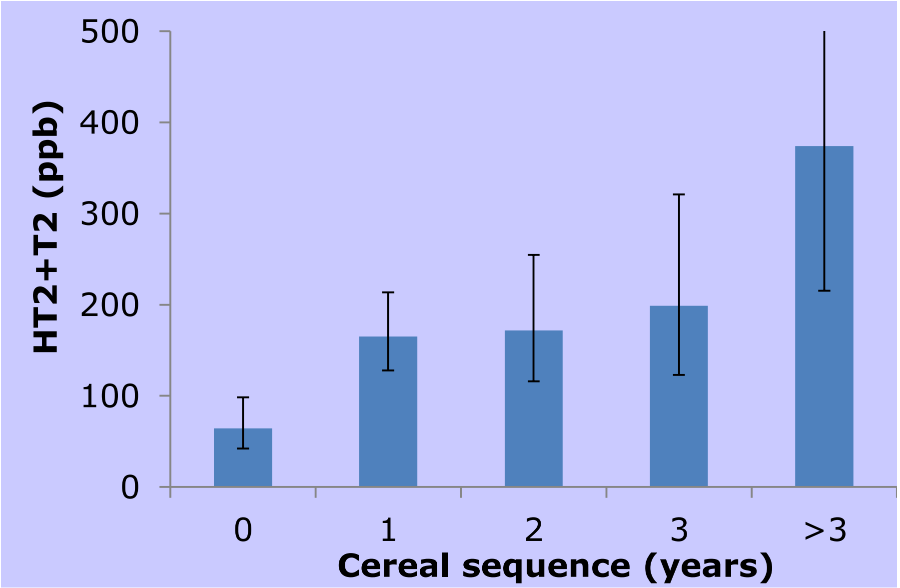


Figure 8: Predicted mean HT2+T2 content of oats classified by the number of cereal crops grown continuously in the previous four years (HGCA data)

4.2 HGCA project RD-2008-3574

Each year (2009-2011), single block samples (1 kg) from replicated plots were collected from each HGCA Recommended List treated (+fungicide, +PGR) oat variety trials from across the UK. Full details of this project will be published shortly (Edwards in press).On receipt of samples they were milled with a 1 mm screen, mixed in a tumbler mixer before a 200 g laboratory sample was collected. Samples were analysed using Ridascreen T2 ELISA kits as described previously to give an estimated HT2+T2 concentration.

For the Recommended List samples the effect of variety was tested for winter and spring oats separately using unbalanced ANOVA with trial site as a block factor. Individual variety predicted mean HT2+T2 concentrations were compared using LSD ($p=0.05$). Datasets from previous years were included where available. Not all varieties are tested in all years as new varieties enter the Recommended List and older varieties are removed. For winter oats, a total of 48 trials were included in the analysis and all varieties were represented in at least 22 trials. For spring oats, a total of 35 trials were included and all varieties were represented in at least 14 trials.

There were highly significant differences between varieties for both the winter and spring variety trials ($p<0.001$) in the 2005-2011 dataset. The overall results are detailed in Figures 8 and 9. As can be seen there is little difference between spring varieties with all varieties close to the overall mean HT2+T2 concentration (133 µg/kg). In comparison, there was a larger difference in HT2+T2 concentrations between winter varieties and a larger overall mean of 403 µg/kg.

There were consistent trends for the winter oat varieties across the Recommended List trials, indicating that the differences in HT2+T2 concentration, which is a measure of the varieties resistance to HT2+T2 producing *Fusarium* species, is stable over time. Naked oat varieties, which lose their husks during harvesting (eg Expression and Grafton), tended to have a lower HT2+T2 content than other varieties. Hendon and Fusion, which are naked short oat varieties, had intermediate HT2+T2 content. Balado is a short-strawed conventional oat variety with a height similar to Fusion (91 cm). Of the current conventional height and husked varieties, SW Dalguise has had consistently low levels while Brochan and Gerald have had consistently high levels of HT2+T2 within Recommended List trials.

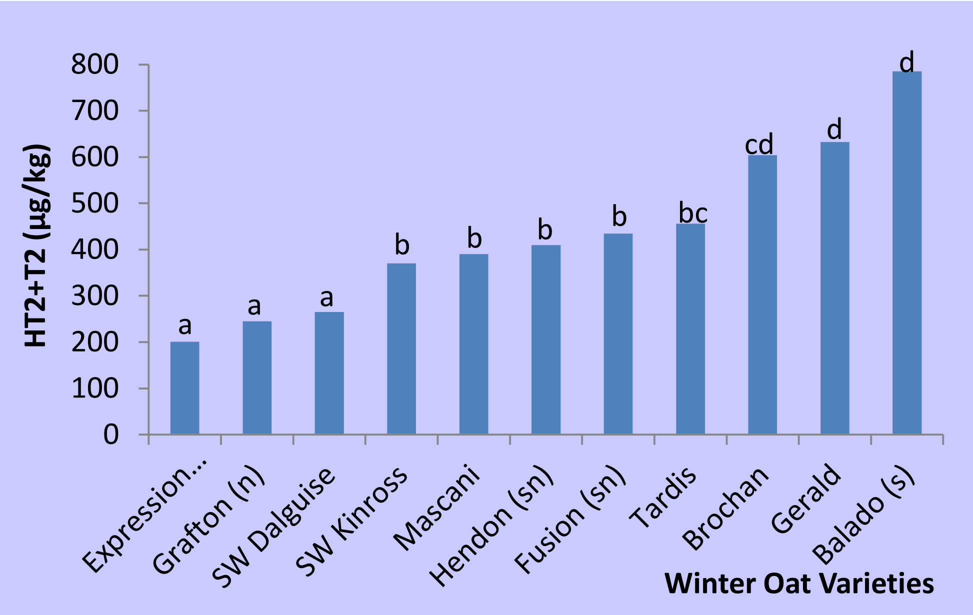


Figure 9: Predicted mean HT2+T2 for winter oat varieties based on a minimum of 22 Recommended List trials conducted from 2005-2011 (HGCA data). Columns with the same letter are not significantly different (LSD; p=0.05).

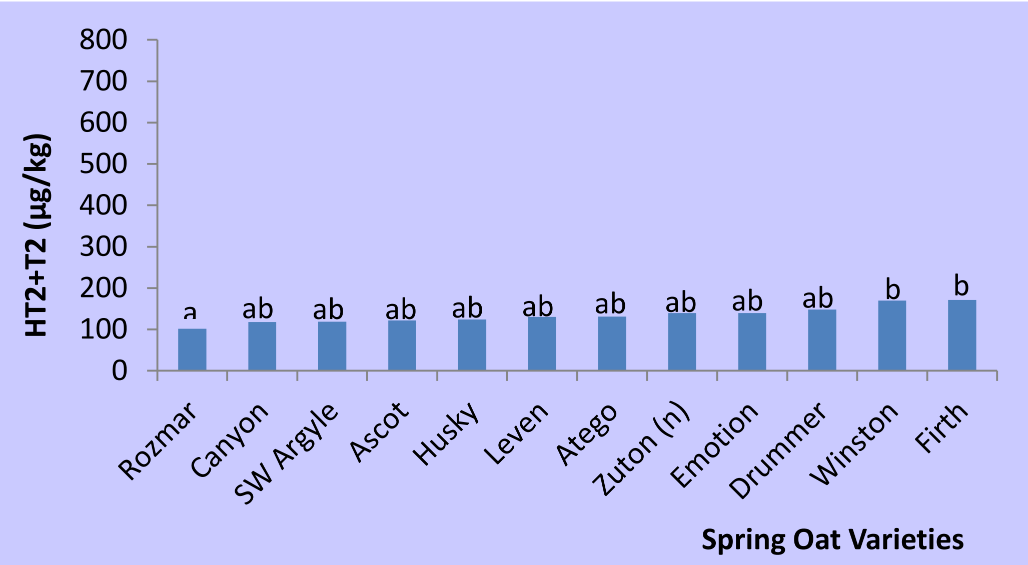


Figure 10: Predicted mean HT2+T2 for spring oat varieties based on a minimum of 14 Recommended List trials conducted from 2005-2011 (HGCA data). Columns with the same letter are not significantly different (LSD; p=0.05).

4.3 Industry funded agronomy trials

Several chemical inputs that are not permitted in organic agriculture may have an impact on HT2 and T2 content. These could include inorganic fertilisers, plant growth regulators (PGR) and/or fungicides. A series of agronomic field experiments were conducted to identify benefits of various agronomic inputs on yield and milling quality of both winter and spring oats. These experiments were designed to test nitrogen rates, use of a PGR (chlormequat) and a range of fungicides. Quantification of HT2 and T2 from the harvested oats from these replicated field experiments allowed the impact of these agronomic factors on HT2 and T2 content to be measured.

All field experiments detailed in this section were agronomy trials funded by industry. and conducted by Scottish Agronomy. HT2 and T2 analysis was conducted and funded by Harper Adams University College. All experiments were conducted as randomised blocks with four replicates. All experiments were repeated over three years (harvest year 2008, 2009 and 2010).

Field experiment 1

A three factorial design with variety (3) x nitrogen rate (3) x PGR (2)
Winter oat varieties: Gerald, Mascani and Brochan
Nitrogen rates: 96, 108 and 120 kg/ha N (applied in three stages: 40 kg at GS22-24, 40 kg at GS31-32 and remainder at GS33-39)
PGR: +/- 1.7 l/ha 3C chlormequat (BASF, Cheadle Hulme, UK) applied at GS31-32

Field experiment 2

A three factorial design with variety (3) x nitrogen rate (3) x PGR (2)
Spring oat varieties: Firth, Leven, Husky
Nitrogen rates: 96, 108 and 120 kg/ha N (all applied pre-emergence)
PGR: +/- 1.7 l/ha 3C chlormequat (BASF, Cheadle Hulme, UK) applied at GS31-32

Field experiment 3

Winter oat variety, Gerald was treated with a range of fungicides at three timings as detailed in Table 1. All treatments other than the untreated control (treatment 1) were treated with the plant growth regulator, 3C 1.75 l/ha (720 g/l chlormequat, BASF).

Field experiment 4

Spring oat variety, Firth was treated with a range of fungicides at three timings as detailed in Table 1. All treatments other than the untreated control (treatment 1) were treated with the plant growth regulator, 3C 1.75 l/ha (720 g/l chlormequat, BASF).

Table 1 Fungicide treatments used in oat agronomy field experiments 3 and 4. Rates quoted are per ha.

Treatment	Zadoks Growth Stage		
	GS 31-32	GS 39	GS 59-61
1	Untreated	Untreated	Untreated
2	Opus 0.4 l Flexity 0.2 l	Opus 0.4 l Amistar 0.75 l	Untreated
3	Opus 0.4 l Flexity 0.2 l	Fandango 0.8 l	Untreated
4	Opus 0.4 l Flexity 0.2 l	Untreated	Opus 0.4 l Amistar 0.75 l
5	Opus 0.4 l Flexity 0.2 l	Untreated	Fandango 0.8 l
6	Opus 0.4 l Flexity 0.2 l	Opus 0.4 l Amistar 0.75 l	Fandango 0.8 l
7	Opus 0.4 l Flexity 0.2 l	Fandango 0.8 l	Opus 0.4 l Amistar 0.75 l
8	Opus 0.4 l Flexity 0.2 l	Fandango 0.8 l	Opus 0.4 l Amistar 0.75 l
9	Opus 0.4 l Flexity 0.2 l	Untreated	Opus 0.4 l Folicur 0.4 l
10	Opus 0.4 l Flexity 0.2 l	Opus 0.4 l Folicur 0.4 l	Untreated
11	Opus 0.4 l Flexity 0.2 l	Untreated	Proline 0.3 l Comet 0.3 l
12	Opus 0.4 l Flexity 0.2 l	Opus 0.75 l Folicur 0.75 l	Untreated
13	Opus 0.4 l Flexity 0.2 l	Untreated	Opus 0.75 l Folicur 0.75 l
14	Opus 0.4 l Flexity 0.2 l	Opus 0.75 l Folicur 0.75 l	Opus 0.75 l Folicur 0.75 l

Amistar; 250 g/l azoxystrobin, Syngenta.
Comet; 200 g/l pyraclostrobin, BASF
Fandango; 100 g/l fluoxastrobin + 100 g/l prothioconazole, Bayer CropScience.
Flexity; 300 g/l metrafenone, BASF.
Folicur; 250 g/l tebuconazole, Bayer CropScience.
Opus; 125 g/l epoxiconazole, BASF.
Proline; 250 g/l prothioconazole, Bayer CropScience.

HT2+T2 concentration was quantifiable in all experiments (Table 2). Eight experiments had an overall mean above 200 µg/kg HT2+T2. Experience would suggest that infection levels are high enough at these concentrations to detect significant treatments effects where differences occur.

Table 2 Overall mean HT2+T2 for agronomy experiments

	Sowing Time	Trial	Overall mean HT2+T2 concentration (µg/kg)		
			2008	2009	2010
Experiment 1	Winter	VAR*N*PGR	172	1297	2917
Experiment 2	Spring	VAR*N*PGR	1253	159	65
Experiment 3	Winter	Fungicide	129	695	2249
Experiment 4	Spring	Fungicide	407	340	68

There were significant differences between the varieties in Experiments 1 and 2 (results not shown). Differences between all UK varieties have been extensively measured within HGCA Recommended List trials with results detailed in Section 4.2. There were no significant differences ($p>0.05$) between the HT2+T2 content of oats irrespective of the nitrogen or PGR treatments and no significant interaction between treatments ($p>0.05$) for either winter or spring sown experiments (Experiment 1 and 2). There were no significant differences ($p>0.05$) between the HT2+T2 content of oats irrespective of the fungicide treatments for either winter or spring sown experiments (Experiment 3 and 4).

5. Agronomic options to reduce mycotoxins (HT2 and T2) in unprocessed oats

Previous studies have investigated a range of agronomic factors and resultant levels of HT2 and T2. Factors considered included:

- Organic production - but unidentified factors
- Previous crops
- Cultivations
- Variety
- Nitrogen Inputs
- Plant Growth Regulator (PGR) inputs
- Fungicide regime

Results of these trials are summarised below:

a) Winter varieties have significantly higher HT2+T2 compared to spring varieties, and are significantly different between one another
b) Previous crop and cultivation – no or small differences, differences not consistent.
c) Cereal intensity – significant differences, increasing HT2+T2 with increasing cereal intensity. Greatest benefit was from using land after grass (i.e. having a long break from cereal production)
d) Nitrogen inputs had no significant effect
e) PGR input had no significant effect
f) Fungicides had no significant effect

Agronomic factors which have been shown to have a significant impact on the HT2+T2 concentration of harvested oats are reviewed and the ability to change oat agronomy based on the available data is summarised in the Sections 5.1 to 5.3 below.

Relationship between cultivation and previous crop

Results in the current project were detailed in Section 3. Results show no clear benefit of the use of a particular previous crop or cultivation practice. Results from observational studies (Section 4.1) also indicate that crop debris may be a source of inoculums. Therefore the position of cereals in the rotation and the impact of cultivation where for example ploughing can bury crop debris from the previous crop but also return debris from the crop grown two years previous to the surface can confound the impact of cultivation.

There is insufficient evidence for a clear recommendation for a change of agronomic practice in favour of one cultivation method over another at this stage. Other policy drivers related to climate change and soil erosion coupled with the cost of production encourage adoption of minimal tillage cultivation for crop establishment[3].

5.1 Varietal impact on HT2 and T2 on oats

UK national Recommended List variety trials are reported in Section 4.2. This data captured over seven harvests show significant differences between varieties. Winter varieties currently available from the recommended varieties lists are prone to higher levels of HT2 and T2 on oats, at levels that can exceed the proposed limits on unprocessed oats entering processing mills for human consumption.

The model developed during HGCA-funded project RD-2007-3332 (Section 4.1) can be used to predict the percentage of samples that would exceed a set concentration for different factor levels. The predicted percentage of oat samples exceeding 1000

[3] Crop establishment is a sequence of events that includes sowing, seed germination, seedling emergence and development to the stage where the seedlings could be expected to grow to maturity.

µg/kg is 17% for winter oats and 4% for spring oats. It should be noted that these values will fluctuate on a seasonal basis as the overall number of samples exceeding 1000 µg/kg has fluctuated from 1 to 30 % from 2002 to 2008.

There is sufficient evidence to support a proposition for agronomic change in terms of change from the varieties currently available for autumn / winter sowing to spring sown varieties. Plant breeding may in the future result in winter sown varieties capable of reliably achieving lower concentrations of HT2 and T2 on unprocessed oats.

5.2 Intensity of cereals in the rotation that includes oats

Observational studies (Section 4.1) indicated a significant relationship between HT2 and T2 on oats and the frequency / intensity of cereals in the rotation. Section 4.1 shows that reducing the frequency of cereals in the rotation and breaking the sequence of cereals offers an agronomic solution to reduce the probability of HT2 and T2 on unprocessed oats being in excess of the proposed limits.

This is not however considered to be a practical solution that might be widely adopted by farmers. Those growing oats are in the main growing them as part of an arable rotation. The nature of arable rotations is such that other cereals will be grown. Theoretically the rotation could be based round a range of horticultural field scale vegetables, root crops and pulses. However, the limitations of soil type, location and more importantly market demand and availability of contract amongst other constraints preclude this as a viable adaptation.

Oats could become a specialist contract grown crop on suitable farms, typically livestock grass based farms. Land could be taken on annually specifically for the production of oats for human consumption. This industry wide adaptation would require specialist growers (and arable equipment not normally found on the grass farm). The scale of operation is such that it is not considered to be a viable proposition for the specialist grower. Returns at current prices would not be sufficient to achieve gross margins sufficient to cover the operational costs. This type of specialist grower taking land annually is practiced in for example the carrot and potato sectors. The financial returns (gross margin) from these crops are however up to ten times greater than that which might be expected from oats.

If the price paid for oats were to increase significantly this adaptation may become viable. However, the option of varietal change would become viable to all arable producers at lower prices. Thus adoption of spring cropping would occur before specialist cropping on grass based farms.

5.3 Recommended change in oat agronomy to be considered in a risk-based analysis

The research has identified a range of possible changes to agronomic practice that could reduce the risk of HT2 +T2 exceeding 1000 µg/kg. The increased capital cost and/or opportunity cost of the range of options is such that the only practical measure that farmers could be expected to adopt is varietal change moving away from winter varieties to spring sown varieties. Therefore, the only agronomic change to be proposed and evaluated is a varietal change to spring sown varieties as a reliable method to reduce the risk of unprocessed oats entering the human consumption supply chain that exceed 1000 µg/kg HT2+T2.

6. Economic evaluation of restricting production to spring sown varieties

6.1 Key assumptions and data sources

It is assumed that the only variable to be considered within the evaluation is with regards the enterprise[4] gross margin of winter and spring sown oat crops.

Data has been made available on the performance of winter and spring sown oat crops. However the sample size cannot be considered as representative of the typical farm on which oats for human consumptions are grown. There are also unexplained anomalies and inconsistencies in the data. For these reason standard data is being used in the evaluation.

Yield data is derived from variety trial data from HGCA recommended lists (HGCA 2012). Variable costs of production are derived from the Farm Management Pocketbook (Redman 2011). Variable costs are the seed, spray and fertiliser cost incurred to grow the crop. The variable costs exclude labour, power and machinery and other overhead costs. The additional costs of drying resulting from later harvest of spring sown oats when compared to winter sown oats is also derived from Farm Management Pocketbook (Redman 2011).

6.2 Factors excluded from the evaluation

6.2.1 Agri-environment schemes

There is a theoretical gain to be made from the change to spring sown crop as overwintered stubbles are attractive to agri-environmental schemes. For example in England, overwintered stubbles could contribute to meeting the requirements for entry level and/or higher level stewardship schemes. Entry level schemes currently generate £30 per hectare support payment. It is not however appropriate to include this in the evaluation for this report. Entry level schemes are whole farm schemes and require greater engagement than simply the area of land used for growing oats. It is assumed that the majority of farmers interested in agri-environment schemes have already adapted farming practice in order to enter the scheme.

Higher level schemes have bespoke agreements designed for the conditions found on the farm. However, higher level schemes are competitive and depend upon factors outside the control of the farmer. Many farmers are unlikely to be eligible for

[4] ***Enterprise*** is an identifiable sector of the farm or horticultural business, for which output includes valuations of unsold stocks produced by the enterprise (Defra 2010)

higher level stewardship due to not being in a priority target area and/or not having sufficient habitat to be competitive in the application process.

6.2.2 Labour, Power and Machinery operational costs

Another theoretical saving from the change to some spring sown oats is that the farm could reduce investment in cultivation and establishment equipment as there is a reduced area of ground to be prepared in the autumn. As oats are in the main minority crops, even on the farms on which they are grown, the theoretical reduction in establishment capacity is quite modest. Any potential saving related to cultivation and establishment could be lost due to delaying the harvest period as demonstrated in Figure 11. Figure 11 is a labour profile for a theoretical 200 hectare combinable cropping farm on which 20% of the cropped area is oats. The figure shows the shift in workload for the farm with the switch from winter to spring sown oats in the rotation.

A further consideration is that spring sown oats are harvested later than winter sown oats. There is a potential harvesting time clash with winter sown wheat. In difficult harvests, it is expected that wheat will be harvested in advance of oats as there is a significant yield benefit of winter wheat over spring oats. The value per hectare of the wheat crop exceeds that of spring sown oats by perhaps £300 per hectare[5].

While individual farms may be able to achieve efficiency and saving, many will not. For this reason changes in operating costs are not included in the evaluation.

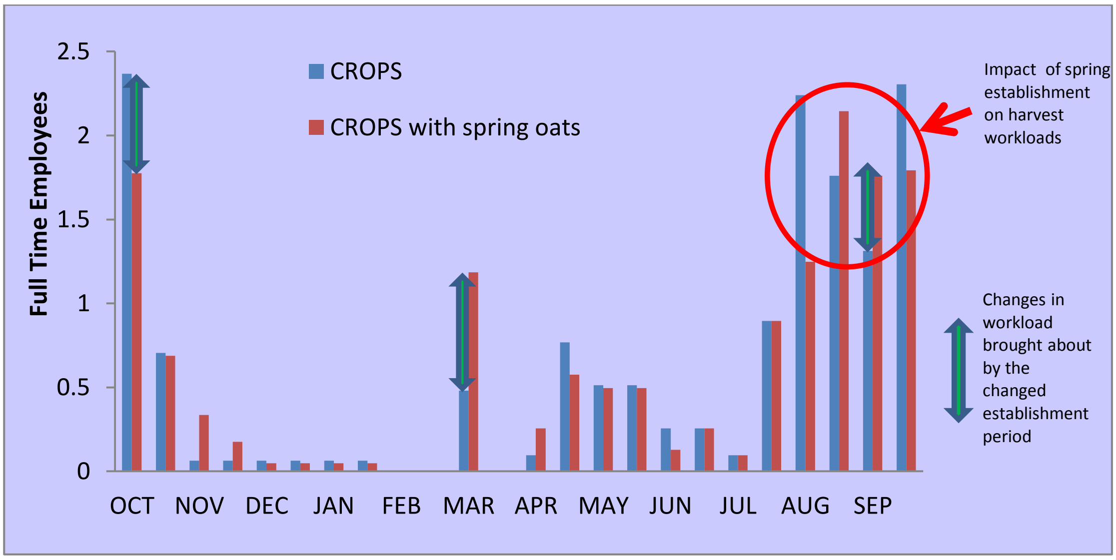


Figure 11: Labour Profile - A 200 ha combinable cropping farm with 20% of cropped area as winter or spring sown oats. Adapted from Standard Man Day (SMD) and seasonal labour requirements (Redman, 2011).

[5] Assumes average yields of 8.8 tonnes per hectare for wheat and 6.6 tonnes per hectare for spring oats; crop value £140 per tonne.

The economic impact assessment was undertaken at enterprise gross margin level as other costs, principally labour and machinery costs were considered to be constant. The justification for this is any change from oats to an alternative enterprise is expected to be adoption of an alternative combinable crop. While there is recognition that there is a theoretical adjustment in the seasonal demand for labour associated with the change from winter sown to spring sown crops, data is not available to quantify the proportion of oat producers utilising employed labour (incurring a wage and National Insurance cost) versus those with work being undertaken by the partners or sole trader in the business (being rewarded via Personal Drawings). Combined with this there would need to be a presumption of actual saving in cost as opposed to a loss of labour efficiency. To help quantify the scale of the potential labour cost change using standard data from The John Nix Farm Management Pocketbook (Redman 2011) an indicative potential labour cost saving from winter to spring sown oats would be £5.57 per hectare which equates to £0.74 per tonne. However allowing for the factors described above the actual figure would be much lower than this, possibly less than £0.10 per tonne. Given all the other variables within the assumptions the labour costs are not considered a material component of the assessment.

6.3 Impact of change from winter to spring sown oats

For the purposes of the assessment the evaluation is restricted to oat production in Scotland and England. It is recognised that oats are grown and/or processed in Northern Ireland and Wales. However the level of assumptions having to be made in the evaluation due to lack of reliable empirical data means that the impact of the proposed change can be assessed using Scottish and English yield data and a single source for costs of production.

Table 3 summarises the mean yield by country over a ten year period. Table 4 shows the impact on yield comparing performance of spring oats with that of winter oats. The data has to be used with caution as the different sites are used within country and from one year to the next. It is however considered a reliable source of an indicative yield reduction that might be expected with the move to spring sown varieties. The average yield impact shown in Table 4 is an arithmetic mean of the annual impact (yield change) over the period 2002 to 2011. Performance data is excluded where winter and spring sown yield are unavailable in the same year.

Anecdotal industry evidence suggests that about 67% of the oats for human consumption grown in Scotland are in fact spring sown oats. The reason for this is the susceptibility of the autumn/winter sown crop to winter kill. In England the suggestion is that about 33% of the oats are spring sown. Variety trial sites tend to be the better sites and probably get greater agronomic attention to detail than typical farm crops. This explains why the evidence of trial yield in Scotland does not support farmers' decisions to grow spring oats as opposed to winter oats.

Table 3: Annual yield data

	WINTER OAT VARIETIES				SPRING OAT VARIETIES			
	Scotland	England	N.Ireland	Wales	Scotland	England	N.Ireland	Wales
	tonnes per hectare							
2011	6.44	6.94	8.33		9.59	4.88		4.91
2010	9.39	8.81	9.14		7.61		6.89	6.59
2009	10.41	8.25	6.29		8.58		7.09	7.93
2008		7.99			8.10		5.40	7.62
2007	8.26	7.84			7.22	5.62	7.08	
2006	11.07	7.70	7.22		7.19	6.07	6.30	
2005	8.54	7.71	7.46		7.86	6.89		
2004	8.66	7.09	7.22	6.36	6.54	7.24	7.20	
2003	7.96	7.95	6.89		7.06	7.88	6.36	
2002	7.04	7.24	6.34		7.38	7.70	3.58	
Average	8.64	7.75	7.36	6.36	7.71	6.61	6.24	6.76
		7.50[6]			7.67[7]			

[6] Average excluding 2008,2009,2010
[7] Average excluding 2008

Table 4: Impact on yield – Spring Oats as compared to Winter Oats

	CHANGE			
	Scotland	England	N.Ireland	Wales
	tonne/ha			
2011	3.15	-2.06		
2010	-1.78		-2.25	
2009	-1.83		0.80	
2008				
2007	-1.04	-2.22		
2006	-3.88	-1.63	-0.92	
2005	-0.69	-0.82		
2004	-2.12	0.15		
2003	-0.90	-0.07	-0.53	
2002	0.33	0.45	-2.76	
Average	-0.97	-0.89	-1.13	

6.3.1 Impact on enterprise output

For the purposes of this assessment the assumed yield penalty in Scotland is taken to be one tonne per hectare and in England it is assumed to be 0.9 tonne/ha. At an industry price of £140 per tonne, this equates to income loss of £140 per hectare in Scotland and £126 per hectare in England.

6.3.2 Impact on production costs

Table 5 shows indicative production costs for winter and spring sown oats. The indicative saving in production cost is £36 per hectare. While the actual cost of production will depend upon the characteristics of the farm, soil quality, pest and weed control issues and the like, the shorter growing season of the spring sown crop reduces the requirement for fertiliser nutrients and pesticide application.

Table 5: Impact on production costs – Spring Oats as compared to Winter Oats

	Winter	Spring	Cost saving
	£ per hectare		
Seeds	63	67	
Fertiliser	155	128	
Sprays	81	68	
	299	263	36
Source: Redman 2011.			

6.3.3 Impact on enterprise gross margin

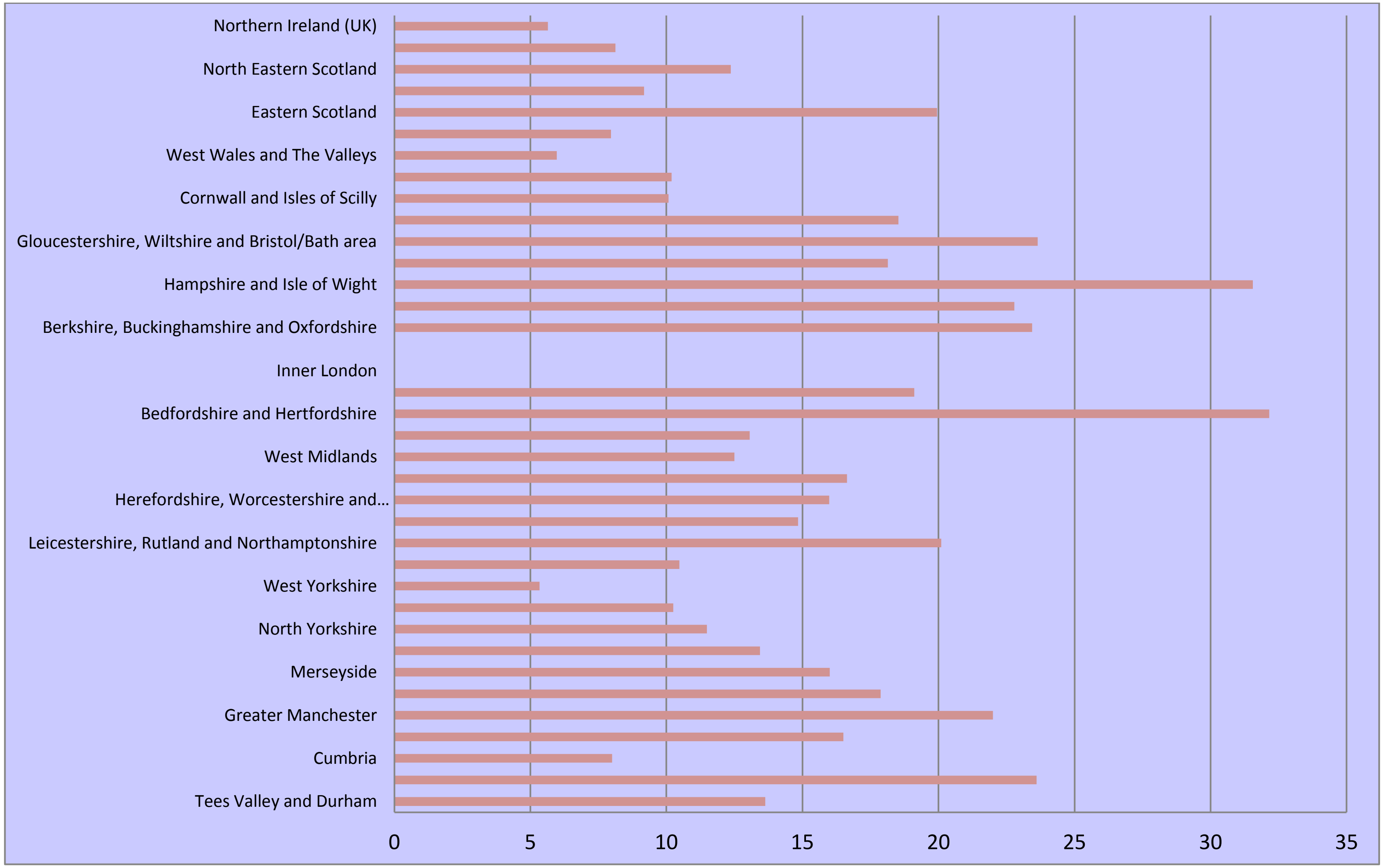
Based on the assumptions stated above the financial impact of the proposed change would be a reduction in gross margin of £104 per hectare in Scotland and £90 per hectare in England. Figure 12 shows the average area of oats grown on farm by region. The problem with this data is that it includes all oats grown on farm and it is felt that the average area in the region is potentially reduced by the impact of livestock farmers growing relatively small areas of oats to meet their on farm feed requirements. An indicative loss to the growers of oats for human consumption in both Scotland and England is in the order of £2,000 to £3,000 per year. This is estimated on the basis of those producers growing oats for human consumption are likely to be growing an annual average of between 20 to 30 hectares per year. In the UK the average area of oats on farms growing oats was 15.26 hectares in 2007 (Eurostat, extracted 29/2/12). However in areas close to main processors, the area per farm is higher. For example in Bedfordshire and Hertfordshire the average area was 32.15 ha and in Eastern Scotland the average area was 19.95 ha.

6.3.4 Impact on enterprise gross margin on commercial farms

As variety trials are carried on the better sites and are likely to benefit from high levels of agronomic input, it is anticipated that the yield penalty on commercial farms may in fact be greater than experienced at trial sites.

An additional factor impacting performance on commercial farms is the apparent volatility in yield from year to year. The data in Table 4 indicates in the nine year period for which data is available the performance range of spring oats over winter oats is 7.03 tonne/ha (-3.88 to +3.15 tonne/ha). While it is accepted that the respective yield data is not from the same trial sites in all years, the data indicates the volatility that farmers could experience growing winter as opposed to spring sown crops. Even accepting the 2011 data for Scotland may be anomalous, the uncertainty of performance (yield) of the spring sown crop will discourage arable farmers from growing spring sown oats. This is confirmed by those farmers growing oats who have responded to the initial draft consultation document.

Figure 12: Average area of oats grown on holdings that include oats in the rotation (hectares)



Source: Eurostat (extracted 29/2/12)

6.3.5 Sensitivity analysis

These budgets are indicative and clearly based on the accuracy of the assumptions used. Table 6 and Table 7 identify the impact of changes to yield loss and variable cost savings on the gross margin per hectare. The -£90 per ha and -£104 per hectare highlighted in the centre of the table relates to the calculated loss per hectare in England and Scotland respectively as a result of a change from winter sown to spring sown oats. The key message to take from these tables is not the specific numbers, but simply the volatility in terms of impact on gross margin per hectare that producers have to consider when planning cropping rotations.

Table 6: Sensitivity to variation in yield loss and variable cost savings (£/ha)

Crop Value (£140/tonne)

Variable Costs Saved (£/ha)	Yield loss (tonne/ha): 0.7	0.8	0.9	1	1.1	1.2
	£ per hectare					
24	-74	-88	-102	-116	-130	-144
30	-68	-82	-96	-110	-124	-138
36	-62	-76	-90	-104	-118	-132
42	-56	-70	-84	-98	-112	-126
48	-50	-64	-78	-92	-106	-120

Table 7: Sensitivity to variation in yield loss and crop value (£/tonne)

Variable Costs Saved (£36/ha)

Crop Value (£/tonne)	Yield loss (tonne/ha): 0.7	0.8	0.9	1	1.1	1.2
	£ per hectare					
100	-34	-44	-54	-64	-74	-84
120	-48	-60	-72	-84	-96	-108
140	-62	-76	-90	-104	-118	-132
160	-76	-92	-108	-124	-140	-156
180	-90	-108	-126	-144	-162	-180

6.4 Competing combinable crops within an arable rotation

In assessing the potential impact of the proposed legislation a key consideration is the economic performance of alternative crops that could replace oats in the rotation. The reason for inclusion of oats in the rotation is a consideration. Oats are sometimes found in the rotation acting almost as the break crop due to the resistance to take-all (most important root disease of wheat). Figure 13 is based on average performance for commodity crops, ignoring premium markets, and illustrates the indicative enterprise gross margins of oats and competing combinable crops.

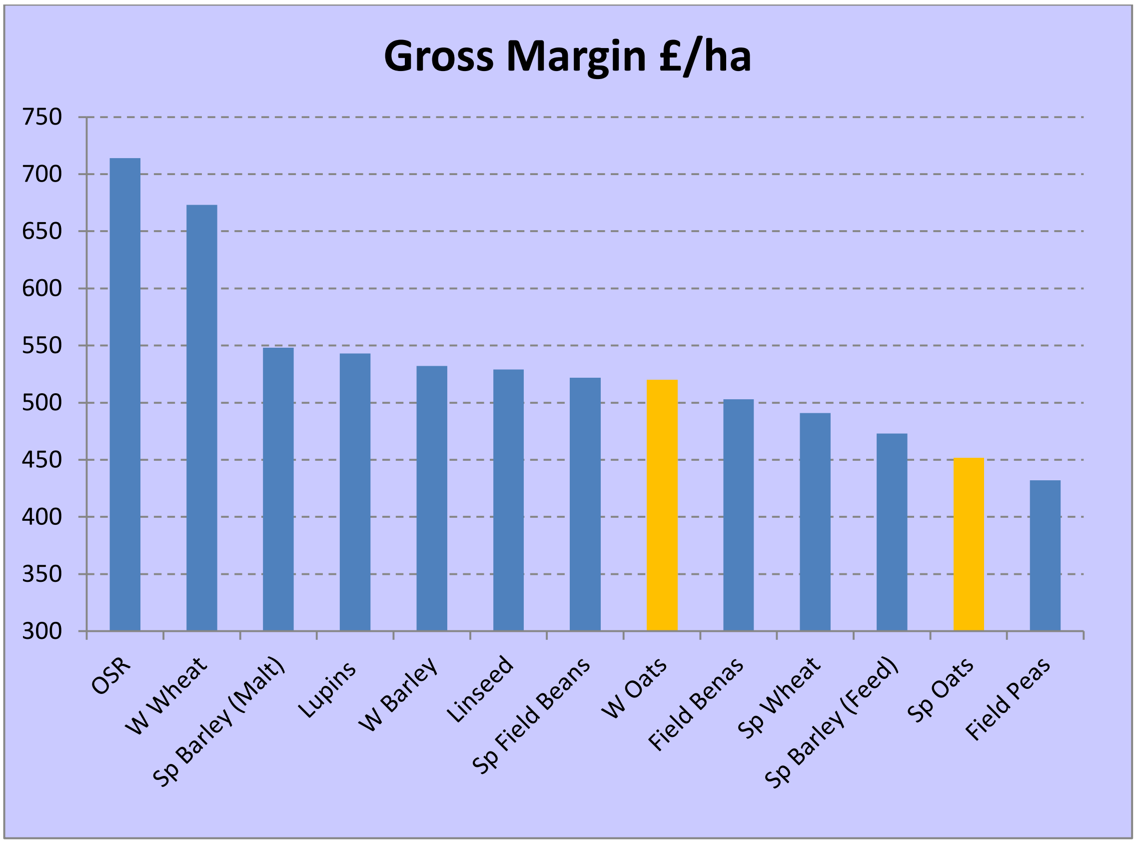


Figure 13: Gross margins for a range of combinable cropping options. Based on data reported in Redman 2011.

Producers currently growing winter varieties of oats and faced with having to change to spring sown varieties in order to increase the probability of meeting the HT2 and T2 specification have a range of alternative crops offering significantly greater return (gross margin £/ha) than spring oats at current prices, as illustrated in Figure 13.

It is beyond the scope of this report to determine which of the range of alternative combinable crops growers would adopt. The decision on crop selection will be influenced by the role oats take in the rotation and the market options available to the grower.

6.5 Additional agronomic and wider business environment considerations

6.5.1 Additional drying costs associated with delayed harvest

In assessing the economic impact of a varietal change, consideration has to be given to the later harvest dates and consequential risk of poor harvest conditions and resultant additional drying costs. As explained in Section 6.2.2 not only is the harvest delayed, there is a greater risk of a harvesting clash with wheat. Given the greater return from wheat (see Figure 13) the expectation is that farmers will harvest the wheat before the oats. The contract cost of drying grain is between £12 and £14 per tonne. For the purposes of evaluation an assumption is made that one in three years farmers could anticipate incurring the additional cost.

6.5.2 Reliability of meeting the specification

Observational data indicates that the probability of failing to achieve the HT2 and T2 discussion limit is 17% of samples from winter varieties as compared to 4% for spring varieties.

The difficulty that all growers face is the lack of an open spot market for oats that fail to meet oat mill specifications. Product specifications for pet and equine markets feeds are likely to preclude use of oats that fail to meet the specification for human consumption. In practice under current and proposed legislation the market will be restricted to local on farm processors of cereal to be fed on the farm. In such circumstance the buyer is likely to have the stronger position in the price negotiation and thus price penalties should be anticipated.

6.5.3 Reliability of establishment of spring sown crops

Discussions with agronomists in England have highlighted a concern about the reliability of being able to establish spring sown crops. Whether due to climate change or just an unusual run of seasons, it appears the reliability of good growing conditions, in particular soil moisture, is questionable. Conditions in recent years, repeated in 2012 have been very dry with low soil moisture levels at the spring crop sowing time. In England and Wales, the HGCA recommended variety yield data indicates the 2011 spring oats yielded 2.0 tonne/ha less than the average recorded in the previous 9 years (see Table 3).

When planning rotations, the first intention of the growers (*plan A*) may be to establish winter sown crops. If there is crop failure or poor crop establishment, the growers then have the opportunity to cultivate and re-establish a spring sown crop (*plan B*). If however the first intention is based on spring sown cropping, there is no opportunity for a "*plan B*".

6.5.4 Reform of the European Common Agricultural Policy (CAP)

The relevance of CAP reform, expected to be implemented from 2014 or 2015 is that the UK position, in terms of direction of travel, is an aspiration for UK agriculture to be self-supporting and not requiring public funding to support commercial activity (Defra Food 2030 Strategy (Anon 2010); Secretary of State presentation to the Oxford Farming Conference 2011 (Spelman 2011)). Current reform proposals do not go as far as this, clearly stating an ambition to maintain pillar 1 support for farming businesses. However, the proposals (European Commission 2011) include greening proposals, modulation and capping elements all of which potentially reduce the net contribution of CAP support on farm profitability.

Included in the producer response to this will be a need to pay even greater attention to the competitiveness and efficiency of the farming operation in order to remain viable.

The proposition that those currently growing winter varieties of oats to supply processors will have to consider spring sown varieties, with the associated reduced gross margin and increased exposure to volatility of return is not compatible with this CAP support driver. Farmers will be developing strategies to minimise exposure to risk, and it is anticipated many will choose alternative crops rather than carrying the risks associated with spring varieties of oats.

6.6 Financial consequence of a HT2+T2 limit without agronomic change

The financial consequence of a limit of 1000 µg/kg for HT2+T2, assuming 17% of winter varieties and 4% of spring varieties fail to achieve specification is modelled in Table 8 for Scotland and Table 9 for England. The model determines the price penalty to be applied to oats that fail to meet the specification and have to be sold locally to livestock farmers, at which the gross margins for winter and spring sown varieties is comparable. The difficulty growers face is there is not a spot market for oats that fail to meet the specification for human consumption. Oats are either grown for a contract market or they are grown for consumption by livestock on the farm.

Table 8 shows that in Scotland at a specification failure rate of 17% for winter sown varieties, the price penalty for crops that fail the specification can be up to 57% before the gross margin matches that of spring sown varieties.

For England the price penalty equates to 62%, with oats achieving as little as £53 per tonne as compared to £140 per tonne for oats meeting specification (see Table 9).

If the yield data from the Farm Management Pocketbook (Redman 2011) were to be used in this modelling as opposed to the HGCA recommended variety trial data, the price penalty is 64%, or a sale price of £50.40 per tonne before the financial performance of winter varieties matches that expected for the spring varieties.

Table 8: Price penalty breakeven analysis for Scotland

Scotland	Winter established crop			
Price Penalty		57%		
	yield	£/tonne	% meeting specification	£/ha
Output	8.64	140	83%	1004
	8.64	60.2	17%	88
	8.64	126.43		1092
Variable Costs				299
Gross Margin				793
Scotland	Spring established crop			
	yield	£/tonne	% meeting specification	£/ha
Output	7.71	140	96%	1037
	7.71	60.2	4%	19
	7.71	136.81		1055
Variable Costs				263
Gross Margin				792

Table 9: Price penalty breakeven analysis for England

England	Winter established crop			
Price Penalty		62%		
	yield	£/tonne	% meeting specification	£/ha
Output	7.50	140	83%	871
	7.50	53.2	17%	68
	7.50	125.24		939
Variable Costs				299
Gross Margin				640
England	Spring established crop			
	yield	£/tonne	% meeting specification	£/ha
Output	6.61	140	96%	889
	6.61	53.2	4%	14
	6.61	136.53		903
Variable Costs				263
Gross Margin				640

6.7 Anticipated farmer response to the proposed changes in HT2 and T2 on unprocessed oats

Given the uncertainty and variability in yield response of spring varieties, concerns over establishment success of spring varieties, the lack of a second opportunity to establish a crop should the first sowing fail and the price penalty that can be taken, it is felt that those producers currently using winter varieties in their rotation are unlikely to change to spring varieties even if the proposals are implemented. Some may continue with winter sown crops and risk the 17% probability for failing to meet specification.

If any change is made to the cropping rotation, it is more likely to be a change to an alternative crop to replace the winter oat varieties rather than a change to spring oats.

7. Implications for oat supply chain

7.1 Supply of UK grown oats

If 17% of winter varieties will fail to meet the specification proposed, then the area of winter varieties will need to increase by 20% in order to maintain the total supply available to the processors.

Alternatively if farmers were incentivised to change to spring varieties, requiring the price per tonne to be increased to compensate for the lower yield, the area of sown to spring varieties would need to increase by between 12 to 14.5 % of the area currently growing winter varieties, to achieve the same total tonnage of production.

In order to increase the margin of spring sown varieties of oats to match that achieved currently by winter oats the price would need to be increased by about £17.50 to £18.00 per tonne. However, the other risks and uncertainties associated with spring sown oats (Section 6.3) will require an additional incentive to be paid to encourage farmers to change (Table 10). The price incentive would have to be restricted to spring varieties to achieve a breakeven position.

Table 10: Price adjustment needed for spring oats to achieve the same margin as winter oats

	Variety Trial Yield response	Price increase required to mitigate the reduced yield	Impact of additional drying costs (1 in 3 years)	Break-even price increase on spring varieties
	£ per hectare	£/tonne	£/tonne	£/tonne
Scotland	-99.80	£13.01	£4.33	£17.34
England	-88.60	£13.40	£4.33	£17.73

Table 10 shows the breakeven price being maintained. Rather than relate this to the winter oats a better comparison is to compare with alternative enterprises. A price increase of £18.00 per tonne would maintain spring oat margins in parity with competing / alternative crops. As 17% of the winter sown crop is forecast to fail the specification the net price of winter oats will depend upon the yield penalty applied to those oats failing the specification. As the price penalty increases, the price increase required to be applied to spring oats declines.

In order to maintain supply of oats at current levels there needs to be a price increase in the order of at least £20 per tonne paid for oats for human consumption. This will improve the gross margins for both spring and winter varieties, making oats a competitive alternative to other combinable crops. Improving the competitiveness of oats will encourage increased plantings, displacing less competitive alternative crops in order to balance production lost from the combination of 17% specification failure for winter oats and 0.9 tonne/ha yield penalty for spring oats.

At current prices no new suppliers will start to produce oats for human consumption as oats cannot compete with alternative crops at enterprise gross margin level.

Establishing the exact tonnages of oats for human consumption from the winter and spring sown crops has proved challenging, with industry indicating total tonnage for consumption of between about 400,000 and 450,000 tonnes per annum. From this an estimated 330,000 to 360,000 tonnes comes from winter sown crops. Taking the mid-point of 345,000 tonnes, the cost to the industry of the price increase required to ensure supply of spring sown oats is in the order of £8million to £9million. Given the small number of processors involved in processing the majority of the crop, commercial confidentiality hinders transparency in terms of the ability of the processing sector to absorb these costs versus needing to pass down the supply chain to retailers and consumers. The presumption is that the cost increase in raw material would have to be passed through to the consumer, an increase in the order of 12.5%[8]. In addition, UK farmers would need to dedicate an additional 9000 to 10,800 hectares of land to oat production, displacing other arable crops currently being grown. The range in additional land required depends upon the combination of change to spring sown varieties and increase in the area of winter sown to cover the anticipated 17% of crop failing the specification for human consumption.

7.2 European oat production - potential for imported oats

This section of the report looks at the production of oats across the EU with a view to the potential of imported oats making up any shortfall resulting from the loss of winter sown oats in the UK. It has to be remembered that some supply chains will preclude this as local production and or geographic provenance is a key factor in product promotion.

7.2.1 European production data

Table 11 sets out the ten countries in the EU producing the greatest tonnage of oats. This indicates that while the UK is a significant producer of oats, there are other countries producing large quantities. The data does not however differentiate

[8] Based on the anticipated £20 per tonne increase over the assumed base price of £160 per tonne for oats.

between oats for human consumption, animal feeds or other uses. The latest data for Poland, Spain and Finland combined indicates total human consumption of less than 75,000 tonnes. These countries as with many others across the EU are predominantly producing oats for animal feeds.

The industry view is that the majority of the oats in these countries produced oats for livestock feeds would not meet the sample specification required for oats to be processed for human consumption in the UK.

Table 11: European oat production by country – top ten by volume in 2011

GEO/TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Usable production	'000 tonnes											
Poland	1070	1305	1487	1182	1431	1324	1035	1462	1262	1415	1334	1382
Spain	954	665	881	881	1043	533	948	1310	1188	923	1018	1079
Finland	1413	1287	1525	1295	1002	1073	1029	1222	1213	1115	806	1102
United Kingdom	640	621	753	747	N/A	N/A	N/A	712	784	744	685	613
Germany	1087	1151	1016	1202	1186	964	830	728	793	826	600	627
Sweden	1151	964	1181	1102	925	746	624	890	820	744	563	776
France	459	485	773	556	606	505	464	415	472	573	448	355
Romania	244	382	327	323	447	378	347	252	382	296	330	369
Italy	318	310	329	306	338	429	395	361	356	315	279	267
Denmark	233	292	276	260	310	315	274	312	290	268	205	227

Source: Eurostat (extracted 29/2/12); N/A – Data not available.

7.2.2 European oat consumption

EU human consumption of oats is set out in Table 12. This clearly shows the dominance of UK and Germany in terms of human consumption, with Table 13 indicating the per capita consumption.

The interpretation of this data is that the UK is probably the most exposed country to the potential negative impact of the loss of winter sown varieties of oats. This conclusion is reached from the combination of the relatively high per capita consumption coupled with the population, and the earlier evidence that spring sown varieties cannot compete economically with winter sown crops due to the lower yield expectation.

Table 12: European human consumption of oats by country – top ten by volume in 2010

GEO/TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
Usable production	'000 tonnes											
United Kingdom	214	224	234	240	216	246	265	313	326	298	306	N/A
Germany	199	178	195	199	234	291	278	224	293	292	290	292
Czech Republic	20	23	25	25	27	23	N/A	N/A	N/A	N/A	35	N/A
Netherlands	28	29	29	26	21	21	25	16	15	33	33	N/A
Poland	45	42	43	41	39	39	36	12	20	20	20	20
Ireland	9	6	12	15	15	12	18	16	13	17	15	N/A
Latvia	4	5	18	20	13	14	16	16	20	16	15	N/A
Portugal	14	14	14	14	12	12	14	13	13	15	14	14
Austria	8	10	11	11	10	10	10	10	11	11	11	N/A
France	10	10	10	10	10	10	10	10	10	10	10	N/A

Source: Eurostat (extracted 29/2/12); N/A – Data not available.

Table 13: European gross human consumption per capita (kg/head) – top ten by volume in 2009[9]

GEO/TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	kg/head											
Finland	6.962	9.947	6.738	7.490	7.643	7.981	N/A	N/A	N/A	N/A	N/A	N/A
Denmark	6.003	5.047	5.589	5.573	6.484	6.098	12.343	N/A	N/A	N/A	N/A	N/A
Latvia	1.679	2.115	7.627	8.534	5.433	5.853	6.800	6.880	8.850	6.724	N/A	N/A
United Kingdom	3.640	3.797	3.952	4.037	3.617	4.097	4.387	5.149	5.328	4.837	4.934	N/A
Ireland	2.381	1.564	3.078	3.784	3.719	2.916	4.275	N/A	2.960	3.827	3.358	N/A
Germany	2.410	2.151	2.354	2.400	2.823	3.515	3.361	2.709	3.553	3.549	3.531	N/A
Portugal	1.373	1.365	1.355	N/A	N/A	N/A	N/A	N/A	1.225	1.411	1.316	N/A
Austria	1.000	1.246	1.364	1.358	1.227	1.232	1.225	1.183	1.286	1.269	1.289	N/A
Greece	0.642	0.274	0.638	0.545	0.543	0.541	0.539	0.537	0.535	0.533	N/A	N/A
Hungary	0.196	0.196	0.295	0.296	0.217	0.277	0.298	0.298	0.348	0.349	0.300	N/A

Source: Eurostat (extracted 29/2/12); N/A – Data not available.

[9] Finland and Denmark inserted at the top of the Table based on their respective per capita consumption data in the early part of the last decade

7.2.3 European exports, imports and self-sufficiency

The import and export data for the EU is set out in Tables 14 and 15. It is not possible to differentiate between oats for human consumption and other uses within the dataset. The data does however indicate the low quantities of oats traded between countries.

Table 14: European oat exports to EU by country – top ten by volume in 2010[10]

GEO/TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	1000 tonnes											
Germany	86	59	68	65	64	98	131	73	100	107	110	123
United Kingdom	86	150	161	201	166	129	77	104	124	144	93	N/A
France	104	37	28	65	71	77	68	48	30	46	61	N/A
Poland	2	1	2	5	0	26	104	49	56	13	39	25
Estonia	0	0	2	1	0	9	19	13	14	25	24	9
Latvia	0	0	0	0	0	3	1	11	13	31	21	N/A
Czech Republic	2	0	0	0	9	27	N/A	N/A	N/A	N/A	18	N/A
Netherlands	7	7	8	7	7	7	16	18	22	9	15	N/A
Austria	8	2	2	8	8	9	13	8	7	6	11	N/A
Lithuania	0	0	0	0	0	3	3	2	9	14	10	N/A

Source: Eurostat (extracted 29/2/12); N/A – Data not available.

Table 15: European oat imports from EU by country – top ten by volume in 2010

GEO/TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	1000 tonnes											
Germany	57	104	100	145	108	184	295	212	304	278	245	268
Netherlands	55	67	53	62	56	48	107	64	77	44	42	N/A
Italy	56	74	52	59	88	60	37	32	44	36	41	N/A
Portugal	7	6	16	16	21	25	6	16	16	19	26	13
United Kingdom	10	7	14	14	23	29	64	24	75	23	24	N/A
Austria	16	16	8	16	16	19	16	15	20	17	18	N/A
Poland	0	13	0	1	0	5	5	7	9	20	16	18
Czech Republic	0	1	2	1	1	2	N/A	N/A	N/A	N/A	10	N/A
Ireland	1	1	1	2	1	2	14	N/A	7	6	6	N/A
Latvia	0	1	1	0	0	3	3	4	3	3	4	N/A

Source: Eurostat (extracted 29/2/12); N/A – Data not available.

[10] It is recognised that Sweden and Finland are significant exporters of oats in the EU, but the Eurostats data does not include returns from these member states from 2004 onwards.

Those member states traditionally producing oats for human consumption would appear to have similar or greater challenges meeting the EU specification for mycotoxins in unprocessed oats as demonstrated by the recent issue of high deoxynivalenol in oat crops of some Nordic countries in recent years. It is therefore concluded that the EU cannot be relied upon as a source of oats for human consumption to make up for a shortfall resulting from the loss of the winter oats for human consumption produced within the UK. Based on this conclusion and linked to the self-sufficiency[11] data shown in Table 16 which is the total tonnage of oats produced as a percentage of that used by each member state, the indications are that there is not a readily available surplus of oats in the EU that would meet the production specification for human consumption in the UK.

To source oats from outside of the EU then would need to consider Russia, Canada and Australia as large producers and/or exporters of oats worldwide. Russia is the world's largest oat producer, but most oats produced in Russia are feed quality and used domestically with very little made available to export markets. Canada has a large surplus of oats for export but has a ready market in the US which is the largest importer of oats worldwide (Agriculture and Agri-Food Canada 2010). Australia is a large exporter of oats for human consumption but, due to its location, the majority of these exports are to Asian countries. High ocean freight costs and the EU import tariff of €89/ton for oats is a major restriction on the importation of oats from outside the EU.

Table 16: European oat self-sufficiency by country – top ten by self-sufficiency in 2010

GEO/TIME	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
	Degree of self-sufficiency (%)											
Bulgaria	100	107	108	102	102	107	109	N/A	96	115	135	
Slovakia	102	74	114	119	115	114	106	122	126	116	129	
Estonia	83	116	91	94	100	124	131	103	116	150	123	
Czech Republic	102	107	96	104	107	134	N/A	N/A	N/A	N/A	122	
United Kingdom	122	132	142	144	137	126	109	123	117	137	119	
Luxembourg	107	144	106	100	247	129	212	153	384	202	116	
France	103	101	105	122	101	105	105	108	103	116	116	
Latvia	97	99	101	100	101	98	102	110	118	111	115	
Poland	97	99	108	96	96	111	96	94	108	100	102	
Austria	95	92	95	96	95	96	95	97	92	97	101	

Source: Eurostat (extracted 29/2/12); N/A – Data not available.

[11] Production as a percentage of consumption

7.3 Additional factors

To complicate the picture and increase the cost to the industry further, the impact of an incentive for oats and competition for land will threaten the supply and demand balance in other commodity areas. Processors of other combinable crops may increase their commodity price to secure supply, resulting in the competitiveness of oats declining further.

The processors will have an additional testing cost in the order of £40/50 per test. The amount and frequency of testing may vary with the season depending upon the levels of HT2 and T2 being detected. Associated with this is the additional delay for the haulier of at least 20 minutes whilst the test is completed. This reduces the efficiency and thus increases the cost of haulage. Finally there is the problem of dealing with rejected loads. Unlike milling wheat and malting barley, where entry to a livestock feed sector is an alternative market, oats rejected from the processing mill do not have a ready access to other markets. Processors in the farm livestock sector as well as farmers milling and mixing on farm will take oats, but only at significant price discounts. Coupled with this is the additional haulage cost and time, all of which contributes to the loss of efficiency throughout the chain.

The inflationary effect of the proposed legislation is much wider and greater than simply considering the UK oat sector. The cost calculations within this analysis are restricted to direct cost of keeping the oat crop competitive with other crops within the arable rotation.

The seasonal variability in terms of oats meeting the proposed specification also has implications for the processors. The observational study detailed in Section 4.1 identified between 1% to 30% seasonal variation in samples exceeding the proposed threshold of 1000 µg/kg HT2+T2. Based on current industry estimates a 30% loss of the winter sown crop suitable for processing equates to about 120,000 to 140,000 tonnes of oats. This volume of oats cannot be reliably sourced from imported oats. It is not a sustainable supply chain if in some years this tonnage is imported and other years it is not needed. The exposure to seasonal variation may be reduced by increasing the supply from imported oats, building long term supply contracts with other producers in other countries. This will however only reduce the exposure not completely mitigate the risk.

UK oat growers are however dependent upon the processors taking all of their oats that meet the specification as there is no alternative market readily available which accepts oats at realistic market price.

A further alternative is that the processors acquire additional storage to facilitate carryover of stock from one year to the next, reducing the dependence on the new season crop. This adds additional cost into the supply chain of about £20 per tonne with storage written off over 20 years (Redman 2011). In addition there is the capital tied up in the crop in store which equates to a further £8 per tonne over 12 months. If this cost were passed on to the growers, oats would be an uncompetitive crop (see Figure 13) with the expectation that UK growers would switch to alternative crops in their rotations.

8. Conclusions

As part of this study eight field experiments to determine the impact of previous crop and cultivation were conducted. There were significant differences ($P<0.05$) in the concentration of HT2+T2 in five of the eight experiments. Significant differences tended to occur when the HT2+T2 concentrations were greater than 200 µg/kg. Results were inconclusive with inconsistent significant differences occurring at different sites and in different years. As such it was not possible to make a recommendation for growers as to the position of oats within a rotation or the choice of cultivation that would reduce HT2 and T2 within oat production.

Other studies have identified significant differences between winter and spring varieties. A regression model based on an observational study identified significantly higher HT2+T2 in winter compared to spring oats. This difference is supported from analysis of HT2+T2 from HGCA Recommended List oat trials which also identified higher HT2 and T2 concentrations in winter compared to spring varieties. The observational study also identified that cereal intensity, as in the number of cereals grown within a crop rotation was significant, with increasing HT2+T2 concentrations as cereal intensity increased. Results from agronomic field experiments found no significant differences between HT2+T2 concentrations for different rates of nitrogen or the application of plant growth regulators or fungicides within field experiments. The only adaptation considered practical from the perspective of the oat growers was a varietal change from winter sown oats to spring sown oats.

Results from this project and a review of other data on the impact of agronomic factors on the HT2+T2 concentration in harvested oats has identified two key factors that appear to provide consistent and worthwhile reductions in HT2+T2 in harvested oats. The first of these is variety, with consistently lower HT2+T2 occurring in spring oat varieties. Estimates based on a regression model of the observational data indicated that the predicted percentage of samples exceeding 1000 µg/kg for unprocessed oats would be 17% for winter oats and 4% for spring oats.

The second factor is the intensity of cereals within rotations, with consistently lower HT2+T2 present in oats grown after few cereal crops within a rotation. Due to the economics of cereal production in the UK, i.e. the high value of wheat, it is unfeasible to grow oats within a rotation with low cereal intensity for most farm enterprises. Most oats that are grown in low cereal intensity rotations would be for on farm use as animal feed.

Based on these results a risk-based analysis was conducted to identify the implications for the oat industry of a switch from winter sown oat varieties to spring sown varieties.

The direct benefit of such a change is a four-fold reduction in the average number of oat consignments entering the human food chain that exceed 1000 µg/kg HT2+T2 from 16 to 4%. Taking the 345,000 tonne estimate of winter sown oats used for human consumption this equates to removing about 41,400 tonnes of oats that exceed 1000 µg/kg HT2+T2 from processing for human consumption per annum.

Broadly the change from winter sown to spring sown oats will result in a yield penalty of about 0.9 tonne per hectare in England and 1 tonne per hectare of crop in Scotland. The production costs for the spring sown crop, in terms of input costs for pesticides and fertilisers, are reduced as compared to the winter sown crop. The impact gross margin is forecast at £90 per hectare in England and £104 per hectare in Scotland. To compensate for this financial penalty, prices paid for oats for human consumption would need to increase by at least £17.50 per tonne.

There would also need to be a 20% increase in the area of land committed to oat production to compensate for reduction due to specification failure and lower crop yields from spring sown crops.

Taking this analysis to industry level, the risk-based analysis identified that the introduction of a limit of 1000 µg/kg HT2+T2 for unprocessed oats for human consumption will increase the costs to the UK oat processing industry by at least £8 million to £9 million, simply to procure oats, if oats are to remain competitive with alternative crops available to the arable sector in the UK.

This cost could be significantly increased as other commodity processors increase the price paid to produce commodities in order that the alternatives remain a competitive viable option for farmers. Other costs would be incurred due to the need for testing and the additional haulage and marketing costs of oats that do not meet the limit and the seasonal variation in the availability of oats suitable for human consumption.

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