Final Project Summary

Project title	Sustaining winter cropping under threat from herbicide-resistant black-grass (*Alopecurus myosuroides*)		
Project number	RD-2009-3647	**Final Project Report**	PR560
Start date	September 2010	**End date**	December 2014
AHDB Cereals & Oilseeds funding	£172,216	**Total cost**	£172,216

What was the challenge/demand for the work?

Black-grass (*Alopecurus myosuroides*) is an increasing problem in arable cropping systems for four main reasons: **1**. **Most black-grass seedlings emerge in autumn –** over 80% of seedling emergence occurs in from August to November. **2**. **Most arable crops are sown in autumn** – in 2014 about 70% of the total arable area of 4.7 m ha was planted with autumn-sown crops, principally winter cereals and oilseed rape. **3**. **Autumn-sown crops tend to be sown earlier than in the past** – the area of oilseed rape has increased 18-fold and the proportion of winter wheat sown in September has increased 10-fold in the last 40 years, from about 5% to 50% of the total area sown. **4**. **Herbicide resistance in black-grass is now very widespread** – by 2013 resistance occurred on virtually all of the estimated 20,000 farms in 35 counties where herbicides were applied regularly for its control.

The early-autumn seedling emergence characteristic of black-grass explains its success as a weed of autumn-sown crops. The earlier crops are sown in autumn, the greater the proportion of total black-grass emergence that will occur within the crop, rather than pre-sowing when plants could be more easily destroyed (e.g. with cultivations or glyphosate). Increasing resistance means that herbicides no longer represent a simple solution and more integrated weed control strategies are needed.

How did the project address this?

The aim was to better quantify the impact of three non-chemical methods for control of black-grass in combination with a robust herbicide programme: (1) time of autumn sowing of wheat; (2) different crop seed rates; (3) impact of spring-sown wheat. The research involved five field trials, and associated modelling work. A review of some relevant additional NIAB herbicide efficacy trials is also included.

What outputs has the project delivered?

The mean effects of delaying sowing winter wheat from mid/late September to early/mid-October over the five field trials are summarised in the table below. Most of the benefits came from delaying sowing by about three weeks from mid/late September to early/mid-October, with additional, but relatively smaller, benefits from further delaying sowing until late October. It must be stressed that these are the *average* effects recorded, and that they will vary between fields and years, as the range between trials show.

Advantages in terms of control of black-grass achieved by delaying sowing of winter wheat from mid/late-September to early/mid-October. Means of five field trials.

	Effect of delaying drilling by approx. 3 wks from mid/late-September to early/mid-October	**Range between trials**	**% of trials giving a positive result**
Black-grass plants m^{-2}	**33% less**	-41 to 78%	80%
Black-grass heads $plant^{-1}$	**49% less – and a similar reduction in seed return**	-15 to 84%	80%
Additional control from pre-em herbicides	**26% more** (from 47% in mid/late September)	5 to 45%	100%

The 33% reduction in black-grass plants m^{-2} due to delayed sowing is remarkably similar to the 31% average value recorded for 19 previous experiments included in the review of Lutman *et al*., (2013). This indicates that the five experiments included in this project produced results which are relevant and broadly applicable and by no means atypical.

The most important finding was the better black-grass control achieved by pre-emergence herbicides applied in later-sown crops. This mean benefit, an additional **26% control** from the same herbicide programme (flufenacet+diflufenican plus prosulfocarb), is substantial, especially when compared to the typical 10 – 20% increase achieved when adding an additional herbicide to a pre-emergence 'stack'. Although the precise reasons have not been investigated, it is probable that this is a consequence of increased soil moisture and lower temperatures at later sowing dates. This **26%** benefit is remarkably similar to the **25%** and **29%** mean benefits recorded respectively in another five NIAB field trials (summarised results are presented in the report) and predicted (in average rainfall conditions) from a model based on data from 375 field trials in which flufenacet-based herbicides were used (Hull *et al*., 2014). This remarkable consistency in results considerably enhances the credibility of the findings.

It is important to clearly distinguish between increasing pre-emergence herbicide performance as a result of delayed drilling and simply delaying herbicide application relative to the crop drilling date. A review of five additional herbicide efficacy trials where both elements were varied showed that herbicide control was maximised by ensuring the herbicides were applied truly pre-emergence and delaying application resulted in poorer control. The reduction in control of black-grass plants as a consequence of delaying application to the early-post emergence stage was ~7% on average in the September and ~32% in the October drilled crops.

Crop yields were assessed on one experiment to demonstrate the impact of the combined effects of delayed sowing date and the consequently lower black-grass population. The highest yield (8.27 t ha^{-1}) was achieved with the crop sown at the highest seed rate at the second drilling date (9 October) and receiving a full herbicide programme. Yield losses were directly attributable to black-grass infestation with 100 heads of black-grass reducing crop yields by of 1.08 t ha^{-1}. The crop yield reduction observed on the untreated plot-halves, although relatively similar for the first two sowing dates (~40%), was dramatically reduced for the latest autumn drilling date (~8%) and for the spring wheat plots (~0.5%). This finding reflects the effect of drilling date on both the black-grass population level and the herbicide performance observed in these trials. Because of the impact of black-grass on crop yields, the September-sown winter wheat yielded less than spring-sown wheat, even when a robust herbicide programme was used.

Increasing seed rate helped suppress black-grass by up to **28%** and this figure is similar to the 26% average value recorded in the review of Lutman *et al*. (2013). However, it was clear that higher seed rates were less effective at reducing black-grass than delayed autumn sowing, which was a much more effective strategy overall due to a combination of reduced black-grass plant populations and better herbicide efficacy.

Seed return was estimated, averaging 87,959 seeds m^{-2} on untreated sub-plots at the first sowing date, highlighting the very high seed production potential of black-grass. However, there was no evidence that the very laborious and time consuming assessments involved, produced results that were any better in terms of quantifying treatment effects than those based on head assessments alone.

Spring-sown wheat appeared to be a good solution due to the substantial (**92%**) reduction in black-grass plants emerging compared with September-sown wheat and the lower number of heads and seed produced per plant. These factors more than compensated for the modest control (mean **55%**) achieved by the pre-emergence herbicides (pendimethalin+prosulfocarb) used in spring wheat.

The modelling studies were a particularly useful component of this project as they used actual mean values from the experimental programme rather than theoretical estimates. The outputs showed that,

Final Project Summary

even with delayed drilling and use of higher seed rates, obtaining adequate control of highly resistant populations is unlikely unless at least 50% control can be achieved with post-emergence herbicides. Where severe resistance results in complete failure of post-emergence herbicides, greater reliance would need to be placed on pre-emergence herbicides. These findings show that delayed autumn drilling and use of higher seed rates, in conjunction with a robust herbicide programme, can make a very useful contribution to reducing the threat from herbicide-resistant black-grass. However, these measures alone will not be sustainable in intensive arable rotations if resistance continues to increase to the pre-emergence herbicides. The results also show that spring cropping has much potential but can be a difficult option especially on the heavy soils which greatly favour black-grass. There are no easy options or ‘quick fixes’, but a return to more balanced rotations and a move away from ever-earlier drilling must be the longer-term goal. Critically, this series of experiments quantified these benefits, not only in terms of the direct effect of delayed sowing and higher seed rates, but also in the more realistic context of a robust herbicide programme. This makes the outputs of this project much more credible, and relevant, than most previous studies on this topic. The results showed that the better control from pre-emergence herbicides is at least as an important factor as the direct effect of delayed sowing at reducing black-grass populations. We believe that this was a novel and highly practically relevant finding.

Who will benefit from this project and why?
The results are directly relevant to farmers with populations of resistant black-grass, as a means of compensating for reduced herbicide efficacy, and the recommendations have already widely adopted as a direct consequence of the effective technology transfer initiatives already conducted.

If the challenge has not been specifically met, state why and how this could be overcome

Lead partner	Rothamsted Research (Stephen Moss/Richard Hull)
Scientific partners	NIAB-TAG (Stuart Knight/John Cussans)
Industry partners	None
Government sponsor	None