THE BCPC WEEDS REVIEW 2019

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The 56th Annual BCPC Weeds Review "*Emerging Science for Weed Control*" took place at NIAB on 14th November 2019, with an audience of over 75 invited delegates.

The 2019 Weed Review started with reviews of two major weed science collaborative projects which have been ongoing in recent years. Firstly, the Black-Grass Resistance Initiative (BGRI) and Integrated Weed Management: PRActical Implementation and Solutions for Europe (IWMPraise)

Rob Edwards (Newcastle University) summarised the BGRI in a presentation entitled: Multiple herbicide resistance in wild grasses; new insights into evolution, mechanisms and diagnosis. BGRI started in 2014 to address the control of the major weed problem in UK arable production. It was a £3.5 million jointly funded four-year project by BBSRC and HGCA that harnessed the latest thinking in biochemistry, ecology, molecular evolution and weed science. It comprised five work packages conducted at Rothamsted Research, FERA and the Universities of Newcastle, Sheffield and York. The project was underpinned by the basic science aimed to improve our understanding of herbicide resistance in black-grass (*Alopecurus myosuroides*) and was integrated with knowledge exchange between the farming and agronomy sectors to meet their needs for weed management.

Black-grass is an outcrossing and genetically highly diverse annual species which predominantly germinates in the autumn. Its distribution and abundance in the UK and NW Europe have increased since the 1980s and it is now the most abundant and problematic weed in the UK.

An initial survey of the severity of the resistance problem was conducted on 71 farms, with 138 fields surveyed and 190 black-grass seed populations collected. Field management data were also collected as well as the impact of the infestations. In sensitivity studies with three of the major arable herbicides (mesosulfuron, fenoxaprop and cycloxydim), populations showed target site resistance (TSR) and non-target site resistance (NTSR) was widespread to mesosulfuron and fenoxaprop. Resistance in black-grass was caused by several reasons (limited rotations and cultural practice; a high dependence on chemical control; reduction in existing arsenal of herbicides with few new modes of action, coupled with genetically diverse weed populations). NTSR is the most problematic as it is not limited to one herbicide or one mode of action. Multiple Herbicide Resistance (MHR) in blackgrass has steadily increased since the 1980s and now affects >1.2 M Ha of the UKs best arable land.

Mechanisms of NTSR in black-grass were investigated using functional genomics and proteomics. They involve upregulation of the xenome and antioxidants. NTSR results in changes in 1,000's of genes although there are minor changes in protein expression. Three types of NTSR proteome were identified which are distinct from other stress responses and have similarities to multi-drug resistance (MDR) in humans. Proteomics of natural and 'forced' NTSR populations shows a consistent association with a protein called AmGSTF1 which is present in all NTSR black-grass populations.

The delegates listen to Jonathan Storkey

A lateral flow assay (LFD), based on detection of AmGSTF1, called BReD (Black-grass Resistance Diagnostic) has now been developed as a diagnostic for MHR in black-grass.

AmGSTF1 structure shows common features to human HsGSTP1, a regulator of MDR and GSTP1 function which can be disrupted with chemical inhibitors and may give rise to the possibility for 'chemical busting' of MHR in black-grass.

AmGSTF1 is not the only protein in NTSR but is also elevated in MHR with *Lolium perenne*. One further finding with AmGSTF1 which challenges the perceived wisdom of tackling herbicide resistance in weeds, is that applying herbicide mixtures does lessen selection for target-site mutations but herbicide mixing has the opposite effect on the marker of NTSR.

Jonathan Storkey (Rothamsted Research) presented the IWMPraise Project overview and its implications for UK weed management including horticultural crops. IWMPraise is a 5-year project which started in June 2017. It involves eight European countries (UK, DL, DK, FR, IT, ES, SI, CH) with more than 40 collaborators, led by Per Kudsk, Aarhus University, Denmark. Work in the UK is mainly being led by NIAB/TAG and Rothamsted Research.

Behind the project is the statement that "We know what we should be doing so why isn't IWM standard practice in the industry?"

There are four key objectives which are aimed to give the following outputs:

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1. To review the barriers (socio-economic and agronomic) to IWM uptake in Europe. 2. To develop novel alternative weed control measures and optimise the efficacy, applicability and use of novel, as well as existing, alternative weed control measures as standalone methods or in combination with other methods and as a result, establish a 'tool box' of validated IWM methods. 3. To design, demonstrate and assess validated context specific IWM strategies for the various management scenarios that address the needs and concerns of end users. 4. To provide on-line information, farmers' field days, educational programmes and dissemination tools, to support the adoption of IWM.

The project is structured to accommodate four cropping systems, i.e. annual narrow-row crops; annual wide-row crops; perennial herbaceous crops; and perennial woody crops. Across these four work packages are others that address, innovation, mental models, soil cultivation and long-term responses and environmental impact

At the heart of the project is a toolbox to: prevent the establishment of weeds from seeds; reduce the impact of weed seedlings on the crops; and reduce seed return from mature weed plants. The project also aims to determine the effectiveness of IWM and identify the trade-offs via a survey across Europe. It is also conducting long-term systems experiments to identify how systems influence weed seed bed populations and determine the impact of systems on weeds?

The presentation ended with the statement that reducing the number of weed individuals should not be the primary aim of IWM, but rather it should aim for increased diversity, evenness and reduced dominance in the weed community.

Darwin Hickman (Rothamsted Research) presented his PhD project entitled "Can allelopathy provide the answer to the black-grass problem?". The primary vision of the project is to identify a crop mix or breeding recommendation that could lead to in-field weed suppression. A second vision is the identity of a bioherbicide produced from allelochemicals found in plant exudate material.

The project attempts to answer two questions: Is there innate ability for wheat to produce allelochemicals that could inhibit black-grass at natural concentrations and if so, what are they? Secondly, do previously identified wheat allelochemicals have potential for black-grass control?

It was stated that modern cereals have been bred in favour of yield over allelopathy and in bioassays with concentrated exudates, ancient wheat varieties have been included. However, one exudate from a combined black-grass/modern wheat mix showed some suppression and chemical analysis revealed this to be a known allelochemical. This has been synthesised along with some analogues and root growth inhibitory activity with black-grass in petri dishes has been demonstrated. Further work is planned for two molecules to assess if activity is retained in soil and solid media with microbial activity and if they are still effective, tests will be conducted in wheat/black-grass competition assays.

Dick Shaw (CABI) addressed the potential of biological weed control in a presentation entitled: "Using natural enemies against exotic weeds – an update on progress in the UK". Following an introduction to the work of CABI, the two options for biocontrol of weeds were addressed. Inundative or "Mycoherbicide Approach" using native pathogens for repeated application or using co-evolved (highly specific) natural enemies of the problem weed species from its area of origin to provide self-sustaining control after a single release. The former is used in high value horticulture, agriculture, golf courses to reduce chemical input/ combat resistance or where conflicts of interest would exclude classical natural control. The latter is the more Classical Biological Control (CBC) and globally has resulted in 7,108 introductions of about 2,685 species as biological control agents and there has been an exponential growth in weed biocontrol in Europe since 2005. Several examples of weed biocontrol successes and projects were presented, including the use of pathogens e.g. rust (*Puccinia* spp) for Himalayan balsam (*Impatiens glandulifera*) control, and the use of insects e.g. *Neochetina eichhorniae* (mottled water hyacinth weevil) for control of water hyacinth; *Listronotus elongatus* a weevil for floating pennywort (*Hydrocotyle ranunculoides*); *Aculus* sp. (Eriophyidae) for control of *Crassula helmsii*; *Aphalara itadori* (a psyllid) from Japan for control of Japanese knotweed (*Reynoutria japonica* (formerly *Fallopia*) *japonica*).

It was concluded that invasive weeds are a serious issue for the environment and economies and CBC can provide a long term, safe solution but it is not a quick fix nor is it straightforward. The technique is on the rise in Europe from a very slow start but the UK is at the forefront of this field in Europe. It was finally emphasised that with invasive species, doing nothing is not a low risk option.

Dana MacGregor (Rothamsted Research) introduced new tools to understand and manipulate black-grass. These included the use of genomic approaches, usually used with model plant and crop species, to understand the biology and survival of black-grass. Two virus mediated approaches were presented which can result in a loss of gene function (virus-induced gene silencing or VIGS) and gain in gene function (virus mediated over-expression or VOX). VIGS has been conducted to suppress AmGSTF1 in the Peldon biotype of black-grass and increased herbicide sensitivity. VOX has been used with the *bar* gene (confers resistance to glufosinate by detoxification) to increase tolerance to this herbicide. This type of study is limited to the laboratory but demonstrates that it is possible to use genomic tools with problem species such as black-grass.

Two post-graduate student posters, were presented over the lunch break, both from the University of Reading. **Nikolaos Koukiasis** presented a poster demonstrating that targeted droplets reduce herbicide inputs in cabbages by at least 85%. **Mahmoud Al Nabhani** presented his poster Obstacles to the implementation of pesticides policy in the Sultanate of Oman.

Following lunch there were two presentations from Nuffield Scholars focussing on weed management. Firstly, **Ben Taylor-Davis** (Hutchinsons) covered "Keeping rotations profitable" based on his understanding of weed management practices learnt from interactions with a number of international weed scientists. A new approach to rotation enhancing nature is being established from these learnings, including: reducing reliance on mechanical tillage associated with repeated applications of herbicides; avoiding stressed weeds, which have lower sensitivity to herbicides; and not using post-emergence herbicides too soon after pre-emergence herbicide applications, which potentially speed up resistance development.

Richard Hinchliffe (Hinchliffe Farms) then covered "Sustainability of no-till and related global knowledge transfer experiences". Based on an understanding of weed control issues in Australia, North and South America, three recommendations were presented. Herbicide boxes and labels should have the Herbicide Resistance Committee (HRAC) classification group shown on them to aid herbicide rotation. The agrochemical industry should help to educate farmers and agronomists about the HRAC classification system and industry recommendations for herbicide resistance need to come from 'one voice' similar to the Weedsmart initiative in Australia, with funding from growers' AHDB Cereals and Oilseeds levy and the agrochemical industry.

The final two presentations covered the management of glyphosate resistance.

Paul Neve, substituting for **David Comont** (Rothamsted Research) gave a presentation entitled "Evolution of glyphosate insensitivity in UK populations of *Alopercurus myosuroides.*" Previous research has demonstrated the extent and key evolutionary drivers of current herbicide resistance in *A. myosuroides* and the aim is to adapt this epidemiological approach to be pro-active, and screen for potential future resistance risks before they become a problem. Four key questions and approaches have been adopted. 1. Does black-grass show variability in glyphosate sensitivity? (glasshouse glyphosate sensitivity assays of UK populations). 2. Does that variability have a heritable genetic basis? (classical genetics on pedigreed seed families) 3. Can glyphosate selection cause further reductions in sensitivity? (sensitivity screening in generation following glyphosate selection) 4. Is there evidence for this occurring in the field? (statistical analysis of UK glyphosate usage).

The question was asked if there was an association between glyphosate usage and sensitivity. Based on LD_{50} values, there is no association with use as a pre-harvest desiccant in the summer but there was, in herbicidal uses over the autumn and spring.

It was concluded that this pro-active epidemiological approach can reveal signatures of directional selection, before field black-grass resistance evolves. There is significant among-population variation in glyphosate susceptibility with a heritable basis for this sensitivity trait which responds to further glyphosate selection and strong (and increasing) selection pressure from glyphosate use. There is evidence for directional response to selection occurring in the field but, there is no widespread field-resistance yet.

Lynn Tatnell (ADAS) presented an update of the glyphosate resistance AHDB project update. In 2015 the AHDB guidelines to minimise the onset of glyphosate resistance were published with four key principles: to prevent survivors; to maximise herbicidal efficacy; to use alternatives; and monitor success. A five-year project was also started in 2015 with the aim to provide practical management guidelines for farmers and agronomists in order to reduce the risk of glyphosate resistance developing in grass-weeds in arable cropping in the UK (also see Clarke, 2018)

The project involved a basic UK data review summary, comparing existing glyphosate use data. In years 1 and 2, a range of container studies were conducted to quantify the effect of glyphosate dose against weed growth stage. A series of field trial studies were conducted between 2016–19. The conclusions from these included that cultivations are essential to reduce plant numbers. Split dose applications (540g/ha) were the most effective for weed control and provided less resistance risk. It was confirmed that delayed drilling leads to less black-grass. For spring crops, timing of cultivations and glyphosate applications should be considered to suit the season. Weather conditions (moisture/temp) also need to be taken into account and dose and weed size are important

In his Chairman's wrap-up, **Richard Hull** (Rothamsted Research) stated that weed science is now in a more prominent position compared to five years ago. This is evident, based on some of the presentations particularly from the BGRI where increased understanding of resistance using new technologies are being applied. This understanding, coupled with improved guidelines for farmers and growers, should help to provide sustainable weed management solutions. However, the future introduction of new chemical solutions, with novel modes of action, allied with non-chemical control and cultivation practices are also essential and it is hoped that these new introductions will be rapidly forthcoming from the industry and will be topics covered in future BCPC Weed Reviews.

Clarke, J. (2018) Protecting Glyphosate Efficacy on Combinable Crops: Resistance, Residue and Responsible Use *Outlooks on Pest Management* **29(6)**, December 2018, 258–261.