Herbicide-resistant weeds pose a major threat to sustainable crop production and tough-to-kill grasses represent a large proportion of the problem. The positive news is that solutions are within every farmer’s reach, with the adoption of integrated weed management practices helping to manage both resistant weeds and minimise further decline in herbicide efficacy.

How big is the problem?
Herbicides make up almost half of global agrochemical sales and without them, it’s estimated that uncontrolled weeds would see crop production decrease by about 35%.
While there is still a healthy portfolio of herbicides available for crop producers to pick from, a decline in efficacy of some modes of action threaten crop yields and economic cropping in some areas.
This decline is due to the evolution of herbicide resistant weeds, which is most acute in the most developed production areas in North America, Europe and Australia, but also rapidly increasing in South America and Asia.
According to the International Survey of Herbicide Resistant Weeds, there are now 255 weed species resistant to herbicides. Between those species, 23 of the 26 known herbicide modes of action have been affected.
A significant 28% of all resistant weeds are from the Poaceae family.
Otherwise known as the grasses, they have an uncanny ability to overcome the selective herbicides thrown at them in cereal grain crops.

Why so many resistant grass-weeds?
Rothamsted Research herbicide resistance expert Paul Neve says that one major factor in the success of grass-weeds in developing resistance is the fact that they are so closely related to the cereal crops they thrive in.
“As farmers are effectively trying to control a grass in a grass, the grass-weed doesn’t have to evolve very far to develop the same tolerance to the herbicide that the crop has itself,” he explains.
Grass-weeds are also tough survivors. Black-grass is the biggest grass-weed threat for cereal producers in western Europe and each of its seed heads produces an average of 100 seeds and each plant typically about 800.
Soil seedbank populations of over 50,000 seeds/m2 have been recorded and annual plant population increases of more than 10-fold are possible.
Different species of ryegrass, e.g. Rigid ryegrass (Lolium rigidum) and Italian ryegrass (Lolium multiflorum) are significant problems for farmers in pockets all over the world, including Europe, North America, Australia and South Africa.

Ryegrasses are also highly-competitive – twice as competitive as black-grass – with thick stands of >100 plants/sq m producing up to 45,000 seeds/sq m in ideal conditions.

So, before herbicide resistance is even considered, high levels of control are required to keep populations of grass-weeds stable or reduce them – in the case of black-grass, 97% control must be achieved just to stand still.

The one weakness of both black-grass and ryegrass is that their seeds are relatively short-lived in the soil. So, if seed return can be prevented, infestations can be substantially reduced over three to five years. This characteristic underpins effective long-term management.

By far the most affected herbicide groups are the Acetyl COA Carboxylase (ACCase) inhibitors, which include the “fops”, “dims” and “dens”, and the Acetolactate Synthase (ALS) inhibitors, which include sulfonylureas.

At the other end of the spectrum, the herbicides least affected by herbicide resistance tend to be residual types applied pre-emergence of the crop, such as flufenacet or pendimethalin, although these are by no means immune.

Partial resistance does occur and builds over time, so these tools should remain effective for the foreseeable future, so long as they are used responsibly.

How does herbicide resistance develop?

There are two main ways resistance can develop – either as target site resistance (TSR) or enhanced metabolism resistance (EMR).

Most herbicides have specific enzymes they inhibit within the plant, known as the target site. With TSR, just one genetic mutation within that target site is required to stop the herbicide inhibiting the enzyme.

In most cases, TSR renders a specific herbicide group ineffective against the mutant weed, like the ALS-inhibitors, but in the case of ACCase inhibitors in black-grass, it is even more complex.

In UK black-grass populations, for example, there are several mutations across three sub-classes within the herbicide group, so populations can have resistance to one, two or even all three, depending on location.

The more worrying development is EMR, where plants evolve in a way that allows them to detoxify the herbicide by breaking it down into harmless compounds before it reaches the target site, effectively shortcutting the herbicidal process.

EMR is of graver concern because affected weeds may be cross-resistant to a broad range of herbicides. For example, if a farmer has been solely reliant on ACCase inhibitors to kill his or her grass-weeds and they develop EMR, switching to an ALS-inhibitor may not work.

Generally, grass-weed populations will have a mixture of TSR and EMR. In the UK, any given herbicide resistant black-grass population typically has about 75% of individuals carrying both, 20% with just EMR and 5% with solely TSR.

Add in herbicide resistance as a factor and a large chunk of the previously-effective post-emergence armoury used to control grass-weeds in cereal crops has been significantly diminished.

Incidence of resistance mechanisms in UK black-grass populations

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Italian ryegrass in winter wheat crop

Image courtesy of Blackthorn Arable

Black-grass seeds

Image courtesy of Blackthorn Arable

Incidence of resistance mechanisms in UK black-grass populations
On top of the two main mechanisms, there is also sequestration, where some plants can restrict the movement of foreign compounds such as herbicides within their cells or tissues to prevent harmful effects. This mechanism has been observed with actives such as glyphosate and paraquat.

Another mechanism of resistance is overexpression of the target protein, where it can be produced in large enough quantities to render the herbicide ineffective.

It is likely that additional resistance mechanisms exist beyond those already discovered.

Why have resistant grass-weeds become a problem?

The simple answer to the cause of resistant grass-weeds around the world is lack of diversity in cropping systems, according to former Australian Herbicide Resistance Institute (AHRI) director and West Australian farmer Stephen Powles.

In his native country, the introduction of the highly effective ACCase herbicide Hoegrass (diclofop-methyl) saw farmers switch to continuous wheat and rely heavily on the one active.

Inevitably, within just a few years ryegrass had developed resistance to diclofop and since then has become resistant to several herbicides, including glyphosate.

In northern Europe, a shift to a more autumn-sown cropping dominated by winter wheat and oilseed rape and established with minimum tillage has seen rotations become much less diverse.

Twinned with a reliance on post-emergence ACCase- and ALS-inhibiting chemistry and resistance to the two chemical groups is now common in Poland, Germany, Belgium, the Netherlands, France, Denmark and Sweden, but perhaps most acute in the UK.

Other herbicide resistant grass-weeds, such as Italian ryegrass (Lolium multiflorum) and loose silky bent (Apera spica-venti), are also a concern in parts of Europe.

But perhaps the most spectacular case of lack of diversity leading to herbicide resistance is North America, where in the mid-1990s glyphosate-tolerant crops were introduced.

Within 5 years 95% of the corn, soya and cotton crops were Roundup Ready and being treated with just one herbicide active to control weeds. Now, there are multiple broad-leaved weeds and grass-weeds resistant to the broad-spectrum herbicide.

“There was a decade or so when US farmers did so well, with good yields, high prices and Roundup Ready crops as a cheap weed control tool. The inevitable happened, however, and they now have the biggest herbicide resistance problem anywhere in the world,” explains Prof Powles.

In the US, weed control costs for some farmers have tripled due to glyphosate-resistant weeds and is a real threat to economic production. Similarly, weed control costs have also ballooned for farmers in the UK where they face infestations of resistant black-grass.
Can the problem be solved?

It is thought that herbicide resistance occurs as many independent events within individual fields and farms. So, while there will be some seed spread via machinery and movement of resistant genes in pollen, this is thought to be minimal within the context of the overall problem.

This is unlike insecticide resistance, where resistant pests can spread over a landscape, so despite the best efforts of a farmer to prevent it, if his or her neighbour is encouraging resistance problem pests may still arrive in his or her crops.

This highlights the fact that **farmers themselves** are in control of the development and spread of **herbicide resistant grass-weed** on their land.

In every case, changing habits can help reduce established grass-weed problems or, on farms where it is absent or at low levels, prevent it becoming a serious issue in the future.

To do so, experts around the world agree that understanding the biology of grass-weeds and use of non-chemical approaches such as crop rotation and cultivations to disrupt the target’s lifecycle are steps in the right direction.

As part of the solution herbicides must also play an important role, with farmers using a diverse range of the remaining effective modes of action to control grass-weeds across the rotation, reducing the risk of resistance developing.

In many situations, pre-emergence residual herbicides are the most effective against resistant grass-weeds and least at risk of breaking down to resistance in the near future.

In the second part of our series on herbicide resistant grass-weeds, we look at some of the practical solutions farmers can employ to manage the problem.

Key points...

**Herbicide-resistant grass-weeds**

- Herbicide resistant weeds threaten global food production
- Grass-weeds account for almost **one third of resistant species**
- **The ability of grass-weeds to compete** and develop resistance is unrivalled
- ACCase- and ALS-inhibitor herbicides **most at risk of reduced efficacy**
- Some grass-weeds have now developed **resistance to multiple modes of action**
- Pre-emergence herbicides **remain effective** but are intrinsically variable as efficacy is reliant on adequate soil moisture
- **Lack of diversity in cropping and herbicide strategy** to blame for resistance
- Farmers can manage resistant grass-weeds by adopting an **integrated weed management approach** that incorporates both non-chemical and chemical control methods