Resistance Management

Resistance to active ingredients

Adama's technical specialists David Roberts (herbicides) and Andrew Bailey (fungicides), along with Professor Per Kudsk of the Department of Agroecology - Crop Health, Aarhus University, Denmark, provide an insight into the growing problem of resistance to active ingredients.

Put simply, resistance to an active ingredient is where a plant or fungal pathogen is able to overcome the dose rate that would previously have killed it. Resistance arises through naturally occurring mutations within the genetic structure of the target organisms. For example, when fungal pathogens infect crops they multiply and increase. Pathogens like powdery mildew have short life cycles and incredibly rapid reproduction. This creates huge potential for mutations among the numerous generations.

Powdery mildew on pea plant

Resistance then arises to a crop protection product when a mutation in part of the population confers insensitivity to the active ingredient. Continued exposure selects these insensitive strains and, providing the mutation has not also carried with it a fitness penalty, they will increase to a point where field resistance becomes apparent.

In a process known as selection, an outside agent such as a pesticide, exacerbates the problem by reducing the population of the original genetic form but failing to overcome the mutated, resistant gene. In the absence of competition, the new form predominates and control is either lost completely or eroded over time, depending on the type of resistance seen.

Modes of resistance

Broadly speaking there are two types of resistance - enhanced metabolism and target site mutation.

Enhanced Metabolism

With this type of resistance, genes within a target organism, such as a weed like Blackgrass (Alopecurus myosuroides), mutate to increase their metabolism rate of the active ingredient. This allows the plant to withstand the herbicide.

This type of resistance often manifests as a reduced control initially rather than a total loss. For example, the enhanced metabolism may overcome the active ingredient but when the dose rate is increased it is once again possible to control the mutated organism. However, further mutations may force the grower to increase dose rates until they become uneconomic or too great a risk to the environment.

Target Site

To exert control, the pesticide's active ingredient needs to act like a biochemical key to a lock at a binding site within the plant's or fungal pathogen's DNA.

When a mutation changes the shape of the binding site, the active ingredient no longer fits and control is lost completely. In this case increasing the dose of an active ingredient will still not control the weed or pathogen. It is potentially a more difficult situation allowing the weed or fungal pathogen to proliferate unchecked.

Other Mutation Types

Septoria in wheat

In fungal pathogens such as Septoria tritici a relatively newly-discovered mutation is known as an 'efflux pump'. The fungal cell has developed to allow it to actively pump out the fungicide, reducing the efficacy of the control measure. A further defence by the fungal pathogen is to over-express proteins. Continuing the analogy of the binding site as the lock and the pesticide the key, over-expressing proteins is a phenomenon where the fungal organism produces so many locks that they are not all filled by pesticide keys and therefore vital processes such as cell respiration can continue.

The Cost and Scale of Resistance

Herbicide Resistance

Blackgrass at emergence in a barley crop

Herbicide-resistant blackgrass is the major concern in weed populations, particularly as the range of active ingredients is limited. Blackgrass resistance first occurred in England in 1982, but occurs across much of Europe where it is a particular problem in the more northern and western countries such as France, Belgium, the Netherlands, and Germany. It is also emerging to some extent in Scandinavia and Poland.

The most widespread resistance is of the enhanced metabolism and target site modes to Acetyl CoA Carboxylase inhibitor herbicides (ACCase). This situation is at its worst in England where herbicide-resistant blackgrass has been confirmed on over 2,000 farms. Testing has also confirmed over 132 cases of resistance to Acetolactate-synthase inhibitor herbicides (ALS) in the UK. Of these ALS-resistant varieties, eight out of nine were target site resistant. In other European countries ALS resistance is less common and is restricted mainly to heavier soils but is of increasing concern.

Germany reported its first case of resistance to ACCase, PSII inhibitors (ureas and amides) in 1983. By 2007 it was also reporting the problem to ALS inhibitors and long chain fatty acid inhibitors.

France reported ACCase resistance in 1993 and ALS resistance in 2006 with the hardest hit areas in the north of the country. In Denmark, about 30% of the blackgrass population is showing resistance to ACCase and ALS chemistry, but the major breakdown is to sulfonylurea. Danish growers face an additional difficulty in combating resistant blackgrass in the form of a pesticide tax. Active ingredients which target long chain fatty acid production in the plant are the most effective option for the Danish grower, but a 100% tax is dissuading growers from using this form of chemistry. Instead the more vulnerable ALS-based products are being used in larger quantities because the tax is lower. Researchers are increasingly concerned that this policy will ultimately give rise to even greater resistance levels.

For the wider EU, herbicide resistance to annual broad-leaved weeds is a growing problem. The three-main species are chickweed, poppy and mayweed. France, Germany, Benelux and the UK all have a problem with these three species which are target-site resistant to ALS inhibitors.

Meanwhile Spain, in particular, has a severe problem with herbicide resistance in poppy. In the past five years, growth in resistance to ALS inhibitors has been exponential. The position now is wherever wheat is grown there will be resistant plants among populations.

Weeds compete for sunlight, water and nutrients so the main impact is seen in reduced yields. The impact of weed species is measured on a scale known as the ‘competitive index’. The index compares what population level of a weed per square metre will result in a 5% reduction in crop yield. Because of its ability to produce tillers, ryegrass needs only five plants/sq m to cause a 5% yield loss.


Blackgrass Seeds

However, even though blackgrass is ranked as less competitive on the index, with 12 plants/sq m needed to result in a 5% yield loss, it is a greater problem. This is because its populations are extremely high. It is not unusual to have in excess of 1,000 blackgrass plants/sq m, creating a dense carpet of weeds in the autumn.

The natural lifecycle is well-suited to our current production pattern, soil types and applied nutrients. Its growing habit of shedding seeds before the crop can be harvested is a major factor in the weed’s prevalence.

As each blackgrass seed head produces 100 seeds, the soil reservoir is considerable. Control levels of 98% of the population are required to keep pace with the weed threat at that level, but resistance means this figure cannot be achieved with herbicides alone. It is commonplace to get a 25% yield loss where blackgrass is present and the cost of a herbicide programme to control it can be as high as £150/ha.

Fungicide Resistance

Across northern Europe the main fungal pathogen problem is Septoria tritici in winter wheat.

In 2012 - a terrible year for septoria in the UK – the wheat harvest was down by as much as 20% in places. Even in a normal year yield losses to septoria amount to 5-10%. The great concern is the lack of alternative chemistry to tackle the problem after the collapse to resistance seen in the strobilurin group of chemicals in North West Europe.

Close up view of blight lesion on leaf of potato plant

Light leaf spot on leaf of oilseed rape plant

It is a stark warning of how a pesticide can be overcome by resistance. Strobilurins offered excellent control on introduction in the late 1990s, but they were in use for only four to five seasons before they were ineffective against Septoria tritici.

Northern Europe, Ireland, France and the UK saw the most rapid breakdown. Ireland was hit first and hardest and probably got just three to four seasons of control. Adding to the concern with strobilurins is resistance to triazoles. This group was introduced in the late 1980s and through the 1990s, but a partial erosion of resistance means they are now less effective against septoria.

The situation is most acute in Ireland. Further erosion of triazole efficacy would leave Irish winter wheat production in a precarious situation with only the active ingredient group known as Succinate dehydrogenase inhibitors (SDHIs) and multi-site chemistry left to protect it.

Adding to this concern are reports of SDHI mutations in the septoria populations in Ireland and southern England in late 2015 early 2016 that may be the first signs of resistance development. Resistance is also seen in other fungal pathogens. Net blotch in barley has developed resistance to azole groups and SDHI chemistry and strobilurins.

Potato blight is a continual concern, but there is still an armoury of products that can cope, as long as growers adopt good practice.

In oilseed rape crop, particularly in the UK, control of the fungal disease light leaf spot is heavily dependent on the azole chemical group. Resistance is already occurring and this could prove to be a big challenge.

Factors Leading to the Resistance Problem

Earlier drill dates

There has been a shift towards growing winter cereals in the pursuit of yields and these have been drilled much earlier. Typical drill dates were previously into October, now 50% of winter wheat is drilled in September. That suits blackgrass because there is no fallow period in which a flush of grass weeds could be allowed to emerge and tackled with a glyphosate application. The almost continuous cropping pattern also allows fungal infections to get an early foothold. The levels of Septoria tritici in wheat crop drilled in early September are vastly different from those drilled later in the autumn. Once the temperature starts to drop the fungal pathogen cannot spread with the same speed.

Changing weather patterns

Warmer temperatures and increasingly wet summers allow fungal disease like Septoria tritici to proliferate. There will undoubtedly be more epidemic years and consequently a greater potential for resistance to develop.

Withdrawal of active ingredients

Legislative action has seen a number of active ingredients removed from the market. This has forced growers into using a smaller number of products as withdrawal has outstripped the development rate of new modes of action. The chemistry is becoming exhausted. This has created an over-dependence on fungicides and fostered resistance.

Stubble burning ban

Legislation also banned stubble burning which was a very effective method of controlling blackgrass and a host of diseases.

Improper use of pesticides

Septoria tritici on lower leaf of winter wheat

The sharp rise and rapid fall of strobilurins is a warning on how improper use can squander a very effective control. While strobilurins produced excellent results against Septoria it had a very narrow and high-risk, single-site mode of action. Recommendations for use were overlooked and it was common for strobilurins to be applied in spray programmes as a lone active ingredient. In addition, they were often sprayed more than once in a season. This took out the competition for the susceptible fungal pathogens and allowed resistant pathogens to dominate. With hindsight, the strobilurins should have been applied with other modes of action alongside them in tank mixes.

Adama commissioned research by ADAS and Rothamsted to demonstrate how the addition of Adama's multi-site product Folpet in the mix each time would have reduced resistance. Modelling results from the study showed Folpet would have doubled the effective life of strobilurins slowing the development of resistance. It is hypothetical, but nevertheless it strongly indicates that if growers had added a multi-site acting fungicide from the start we could have had five more years of strobilurins to control Septoria.

Management Controls and Techniques To Reduce Resistance

Drilling time

Time of sowing is key in the fight against weeds and diseases. Delaying drilling dates as late as possible is the main advice, but it is a gamble because of the changing weather as autumn progresses.

The trend of drilling winter wheat before the end of September allows no fallow period, but if dates can be delayed later into October, it allows flush of weeds to emerge that can be tackled with glyphosate. The break also cuts the risk of fungal pathogen development on the crop. Lower temperatures in October slow the pathogens' development and there is less time per se for the fungal pathogen to get a foothold.

Better observation/spotting a problem earlier

As the important azole group of fungicides has lost up to 60% of its curative effect on Septoria tritici it is vital to stay ahead of infections. So, improving observation of the crop is extremely helpful. For grass weeds, walking the fields and mapping species and poor yield areas with a handbook or GPS will allow better targeted patch-spraying.

Cultivation techniques

Min-till techniques are advised for blackgrass control. Research shows that herbicides work well in the top 5cm of the soil. Cultivating deeper will, therefore, afford the blackgrass seed some protection. Contrary to that theory, ploughing blackgrass seed down to 15-20cm reduces its viability by about 80% in four years, but there is a risk with this strategy that some seed will be ploughed back up. The advice, therefore, is to use min-till for at least four seasons so that any returning seed at ploughing is less viable.

Rotation

A good rotation is hugely important in disrupting the development of weed and fungal pathogens. Opting for a spring crop in the rotation provides a mechanical or chemical control period for weeds while the fungal pathogens are denied a host cereal crop to overwinter.

Rogueing


Zero tolerance: rogueing the few blackgrass survivors

Married with better observation, rogueing can be effective. However, big plant populations are impossible to tackle.

Variety choice and seed rates

Variety choice is a major factor in integrated management and resistance control in fungal pathogens. Growers have opted for high-yielding varieties but it is now vital to look more towards disease resistant characteristics. There are now much better yielding types with strong host resistance. For blackgrass, using a variety that has a more prone growth characteristic may provide some help to outcompete the emerging weeds. Trials looking into the effect of increasing seed rates to further compete with the weeds are ongoing.

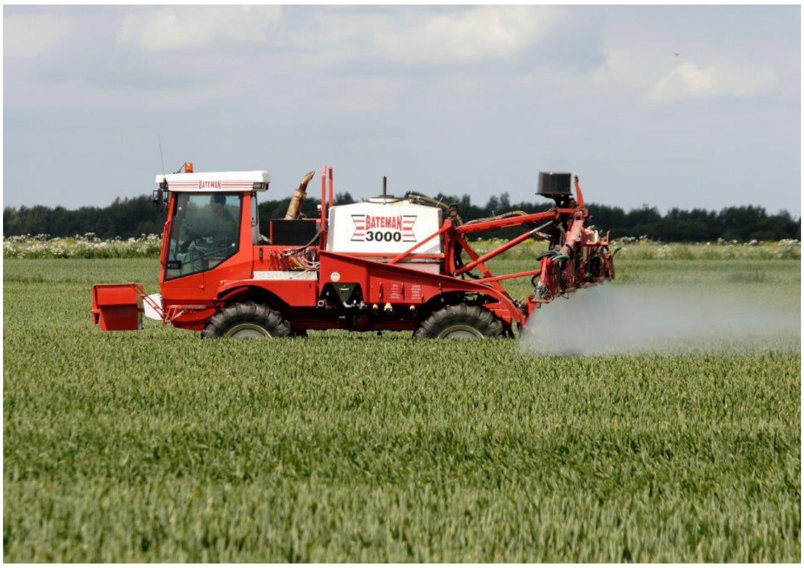
Cleaning equipment – balers, combines, trailers

This is a very simple way to minimise the threat of pathogens and weed spread. Airlines are excellent at blowing lodged seed from tight spaces in equipment. In addition, harvesting the worst-affected areas last will help cut the risk of spreading blackgrass and fungal diseases into cleaner fields.

Reduced resistance risk spray programmes

The key to reducing the risk of both fungicide and herbicide resistance is to use products in a spray programme with different modes of action. This reduces the risk of allowing any one type of mutation to proliferate.

Fungicide application programme



Self propelled sprayer applying fungicide to wheat crop at T3 timing

The planning of a fungicide application programme should include triazoles, SDHIs and multi-site acting products.

Multi-site products carry the lowest resistance risk while the SDHIs and azoles have a narrower scope and need protecting. While retaining curative control of rusts, the azole group has lost some of its curative efficacy on Septoria tritici so should be looked upon as a protectant in the strategy. In fact, trials have shown that the preventative effect of azoles has reduced by 20% over the past 10 years, while their curative efficacy has fallen by 60% or more.

Programmes should, therefore, be founded on multi-site chemistry and looked upon as a protective strategy. That means keeping ahead of fungal pathogens as once there is a significant build-up in the crop, control will be limited.

Application timing T0 (typically pre-stem extension, targeting leaf 4) - Use a multi-site such as Adama's folpet- based product Arizona (straight folpet at 500 gai/l) or Manitoba (folpet at 375 gai/l plus epoxiconazole at 50 gai/l). Folpet provides three stages of biochemical protection and are therefore less susceptible to resistant mutations.

Application timing T1 (post stem extension, targeting leaf 3 emergence) - Adama's epoxiconazole, Cortez, can be used at this stage to protect against rusts and Septoria. As SDHIs are limited to two applications per season they are most commonly employed at T1 and T2 stages. Manitoba (folpet at 375 gai/l plus epoxiconazole at 50 gai/l) is useful here alone or in tank mix with straight SDHI.

Application timing T2 (targeting leaf 1 emergence) – This is a crucial growth stage and a multi-site, azole plus SDHI will provide the most protection. Manitoba is well-suited and an easy combination together with an SDHI.

Growth stage T3 (ear emergence) – Choices are limited here. A good solution is Adama's Orius P, a versatile fungicide, containing two azoles, prochloraz and tebuconazole. This provides fusarium and microdochium control on the ear.

Herbicide application programme

The current accepted thinking, when building a programme for controlling blackgrass in winter wheat, is to use 240 grammes of active ingredient per hectare (gai/ha) of flufenacet in the programme.

This would normally be achieved by applying 120 gai/ha flufenacet as a pre-emergence (crop and weeds) treatment, followed by an additional 120 gai/ha post-emergence, most often in a tank mix with iodosulfuron-methyl + mesosulfuron-methyl. Ideally, for optimum weed control, the post-emergence application should target blackgrass plants at two leaves. However, this may not be possible in all autumn periods as an interval of six weeks is required between sequential applications of flufenacet-containing herbicides.

It is very important for the first application to be a true pre-emergence, and not delayed until some emergence of crop/blackgrass has begun. The Adama herbicide Herold (400 g/l flufenacet + 200 g/L diflufenican (DFF)) applied at 0.3l/ha delivers 120 gai/ha flufenacet and 60 gai/ha diflufenican, so is an excellent choice for the pre-emergence treatment.

Another very useful active ingredient in blackgrass programmes is pendimethalin (PDM). This is available from Adama as the product Anthem, and is also available as a mix with DFF in Omaha 2, and with chlorotoluron (CTU) + DFF in Tower (i.e. three active ingredients in one product). Straight Anthem (PDM) is often added to the post-emergence application iodosulfuron-methyl + mesosulfuron-methyl to improve activity on blackgrass.

Adama also has the product Hurricane (500 g/l DFF) which can be added to Herold to bring the dose of DFF up to 120 gai/ha - the maximum allowed. This improves activity on blackgrass.

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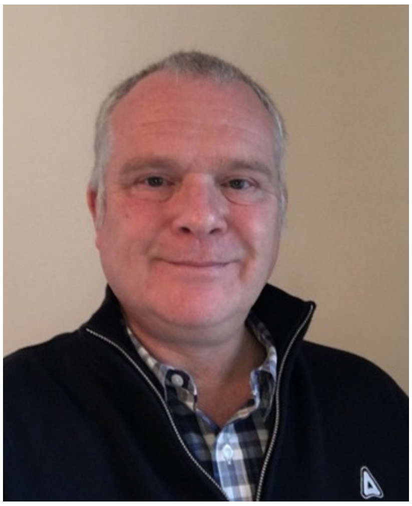

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