Can we break the multiple resistant wild oat cycle?

*The research view – Tony Cook NSW DPI*

There are many infestations of multiple resistant wild oats in the northern grain zone, particularly in northern NSW. However as recently as 15 years ago, this phenomenon was relatively rare in this region.

Why the sudden “blow-out” in these hard to control wild oat populations? And can we break the cycle of these multiple resistant populations?

Before we can answer these questions we need to understand the life cycle of wild oats and past farming practices that led to herbicide resistance.

**Life cycle of wild oats and the evolution of herbicide resistance**

Wild oats persist in cropping systems due to their seed production. Although the relatively short-lived wild oat seed bank has a minor role, the survival of a small proportion will produce enough seed to replenish the seed bank, thus guaranteeing the persistence of wild oats.

A good way of thinking about this is to start with a seed bank of 10 seeds per square metre. Assuming that 90% of these seeds germinate (9 plants), that would leave one seed per square metre in the soil. Of the 9 plants that emerge, post-emergent sprays would normally kill 8, resulting in one surviving plant. This plant could have survived due to several reasons; shading, wheel tracks, poor application or possibly herbicide resistance. Seed production from this survivor needs to be at least 9 seeds to top up the seed bank to the original level. If herbicide resistance is the cause of survival, the evolution of herbicide resistance commences. The likely seed production from resistant individuals would be at least 100 to 200 seeds per plant. The final result is a “blow-out” in resistance.

The repeated practice of relying upon a single application of post-emergence herbicides, without controlling these survivors has meant that small patches dominate paddocks and farms. Those farms that rotate from winter to summer crops have fared well in general, as this breaks the cycle of resistance. However, there are some regions that cannot grow summer crops due to restrictive rainfall in warmer months.

Scientific evidence has shown that two successive winter fallows are required to reduce seed banks by 99%. Therefore, summer cropping or long fallowing can be seen as a high priority strategy.

**The history of multiple resistance in wild oats**

As one herbicide group fails, farmers changed their herbicide to an alternative mode of action (MOA) group. A simple change from MOA group ‘fop’ to ‘dim’ (both group A herbicides) was usually enough to combat this problem, albeit temporarily. However, as explained in the previous text, all it takes is one individual resistant to the ‘dim’ chemistry and the start of the multiple resistance cycle begins. The abuse of ‘dim’ herbicides with no strategy to control survivors was a recipe for entrenched multiple resistance. This is one example of the development of multiple resistance in wild oats.

Another case of multiple resistance can arise from cross-resistance. A common example is ‘fop’ resistant populations have developed resistance to Mataven® (Group Z) without any history of Mataven® use. This is caused by the mutation on the enzyme that affects ‘fop’ and Group Z herbicides simultaneously.

So have we learnt from these past errors in management when the new generation of Group B wild oat herbicides were released in the early part of this decade? The answer is no. Grain growers have used these new Group B herbicides like the ones that failed before. It is no
wonder that there are now populations that are resistant to all in-crop wheat post-emergence herbicides.

*It is time to make some radical changes to ensure that we preserve the remaining effective herbicides.*

What options are available to use?

Populations susceptible to at least one post-emergence herbicide

The first option to consider is pre-emergence herbicides. Previously, the use of trifluralin (Group D) or Avadex® Xtra (Group J) was not common. Their limited use implies the chances of resistant individuals in populations are extremely low. This can be seen as an opportunity, as these herbicides have a role to play in reducing wild oat numbers as the crop emerges. However, if all post-emergence herbicides are no longer effective the continual use of pre-emergence herbicides is not viable for two reasons. The first reason is that pre-emergence herbicides usually result in 70 to 90% control and small densities can rapidly thicken up, as survivors from these treatments tend to be large and produce many seeds (up to 500 seeds per plant). Another reason not to solely rely upon pre-emergence herbicides is the likelihood of developing resistance to them.

To maximise the control achieved by pre-emergence herbicides, a tank mix of trifluralin and Avadex® Xtra was used. Apart from belonging to different herbicide groups, the herbicides complement each other by acting on different parts of the weed. Avadex® Xtra affects new shoots that are pushing through the soil but may leave many soil surface germinating wild oat plants. However, trifluralin kills seedling wild oats by preventing root development. Therefore, surface germinating oats have less chance of surviving if their roots are prevented from growing.

Successful use of pre-emergence herbicides is only as good as follow-up control measures. Provided that there are some useful in-crop post-emergence treatments left, there is some hope to get control of wild oats.

This was best demonstrated by NSW DPI research undertaken in 2007. A Group A (fop and dim) resistant population from North Star was sprayed with combinations of pre- and post-emergence herbicides. The results presented in table 1, show that using a combination of pre- and post-emergence herbicides could severely reduce wild oat seed production. Without this seed production, wild oat populations cannot persist.

Table 1: Effect of using two effective treatments on Group A resistant wild oats

<table>
<thead>
<tr>
<th>Treatment(s)</th>
<th>Rate of product/ha</th>
<th>Herbicide group(s)</th>
<th>Wild oat plants per m²</th>
<th>Wild oat seeds per m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Topik® (post-em)#</td>
<td>65mL</td>
<td>A</td>
<td>5.0</td>
<td>180.9</td>
</tr>
<tr>
<td>Wildcat® (post-em)*</td>
<td>300mL</td>
<td>A</td>
<td>2.4</td>
<td>123.3</td>
</tr>
<tr>
<td>Achieve® (post-em)*</td>
<td>380g</td>
<td>A</td>
<td>1.0</td>
<td>43.8</td>
</tr>
<tr>
<td>control</td>
<td>----</td>
<td>----</td>
<td>2.1</td>
<td>90.7</td>
</tr>
<tr>
<td>Trifluralin 480 (pre-em)</td>
<td>1.5L</td>
<td>D</td>
<td>0.8</td>
<td>47.8</td>
</tr>
<tr>
<td>Avadex® Xtra (pre-em)</td>
<td>1.6L</td>
<td>J</td>
<td>0.3</td>
<td>9.4</td>
</tr>
<tr>
<td>Atlantis® (post-em)*</td>
<td>330mL</td>
<td>B</td>
<td>0.1</td>
<td>4.2</td>
</tr>
<tr>
<td>Hussar® (post-em)*</td>
<td>200g</td>
<td>B</td>
<td>0.2</td>
<td>2.3</td>
</tr>
</tbody>
</table>

| Avadex® Xtra (pre-em) + Mataven® 90 (SST)# | 1.6L + 1.875L | J + K | 0.0 | 0.0 |
| Mataven® 90 (SST)#               | 1.875L           | Z     | 0.1 | 0.4 |
| Atlantis® (post-em) + Mataven® 90 (SST)# | 330mL + 1.875L | B + Z | 0.0 | 0.0 |
| Avadex® Xtra (pre-em) + Atlantis® (post-em)* | 1.6L + 330mL | J + B | 0.0 | 0.0 |
Wild oat seed production figures in Table 1 highlight the poor level of control from Group A herbicides. It also demonstrates that solely relying upon herbicides such as trifluralin and Avadex® Xtra will result in sufficient seed production to perpetuate wild oat seed banks.

The tactic of using a pre- and post-emergence herbicide is sound provided that wild oats are susceptible to post-emergence herbicides. More radical tactics are required if wild oats exhibit resistance to most in-crop post-emergence herbicides.

**Populations resistant to most post-emergence herbicides**

Alternative cropping options were investigated to combat multiple resistant wild oat populations in 2006 in winter dominant rainfall areas.

Table 2 below shows a range of options that were tested at Collie, NSW on a wild oats population with resistance to Group A and B herbicides, as well as Mataven (Group Z). Although this only represents one season’s data, it shows that wild oat seed set can be minimised without the use of sorghum or other summer crops.

It is possible to grow crops other than wheat in winter dominant rainfall areas and take control of wild oats. New technology crops such as Clearfield canola, that allow the use of OnDuty®, may not be effective if Group B resistance to Hussar® and Atlantis® exists. The consequences of herbicide resistance is reliance on more herbicide with different mode of actions (4 herbicide groups used per crop, as shown in Table 2). This will result in additional financial stress and may not be applicable to regions with lower historical gross margins. Please ensure you have wild oats tested for their herbicide resistance status prior to undertaking changes to your farming system.

Table 2. Effect of different rotation treatments on the seed set of Group A, B and Z resistant wild oats, Collie, NSW, 2006. GRDC Project DAN00079.

<table>
<thead>
<tr>
<th>Enterprise</th>
<th>Treatment(s)</th>
<th>Herbicide group(s)</th>
<th>Wild oat seeds/m²</th>
</tr>
</thead>
<tbody>
<tr>
<td>TT Canola</td>
<td>trifluralin 2L/ha + Avadex® Xtra 1.5L/ha + atrazine 500g/L 3L/ha + Sertin® 1L/ha</td>
<td>D + J + C + A</td>
<td>0.5</td>
</tr>
<tr>
<td>Canola</td>
<td>trifluralin 2L/ha + Avadex® Xtra 1.5L/ha + Dual® Gold 0.25L/ha + Sertin® 1L/ha</td>
<td>D + J + K + A</td>
<td>15</td>
</tr>
<tr>
<td>Clearfield® canola</td>
<td>OnDuty® 40 g/ha</td>
<td>B</td>
<td>469</td>
</tr>
<tr>
<td>Chickpea 35 cm row</td>
<td>trifluralin 2L/ha + Avadex® Xtra 1.5L/ha + Simazine 500 g/L 2L/ha + Sertin® 1L/ha</td>
<td>D + J + C + A</td>
<td>1</td>
</tr>
<tr>
<td>Chickpea 75 cm row</td>
<td>trifluralin 2L/ha + Avadex® Xtra 1.5L/ha + Simazine 500 g/L 2L/ha + Gramoxone® 2L/ha (inter-row)</td>
<td>D + J + C + L</td>
<td>11</td>
</tr>
<tr>
<td>Wheat</td>
<td>trifluralin 2L/ha + Avadex® Xtra 1.5L/ha + Atlantis® 30 g/L</td>
<td>D + J + B</td>
<td>14</td>
</tr>
<tr>
<td>Wheat</td>
<td>KIH – 485 150 g/ha (Experimental herbicide)</td>
<td>???</td>
<td>35</td>
</tr>
</tbody>
</table>
**long fallow** | Flame® 200 ml/ha + glyphosate | B + M | 0

Note: This wild oat population was still susceptible to Sertin®, yet resistant to Topik®, Wildcat® and a range of other Group A herbicides. The Flame® in the long fallow treatment did not work (due to suspected resistance) and complete control was achieved with glyphosate.

**Know what you are dealing with – test for what does and doesn’t work**

To ensure effective weed control the farmer must know which herbicides still kill the population. This means that some form of herbicide resistance testing must be conducted. Farmers should be planning for next season already.

1) Test for ALL herbicide modes-of action. This will be cheap insurance against herbicide failure next season.

2) Pick your HIGH RISK paddocks first. These are the ones that have received more than 6-8 Group A herbicide applications, particularly where weed numbers have been high.

There are 2 main options.

1. Seed testing
   Seed can be collected at the end of the season and sent to the testing service who will give a report on the level of resistance. Due to the nature of the test, results won’t be available till March-April next year. See contact details below.

2. The Quick-test
   This involves digging up live plants and sending them to the testing service. The weeds are then trimmed, potted, regrown and sprayed. Turn around time is 4 to 6 weeks. If done early in the season results can be returned to make accurate management decisions on the current crop. However, samples can be submitted now, for planning next year’s program. See contact details below.

If there is a problem in this year’s crop, a field trial can be conducted comparing higher rates of a range of herbicide MOA’s, however this form of testing requires professional interpretation due to variations in weather, weed size, soils and application. Field trials can give useful information for planning, but not action this season, unless you are willing to spray out patches of crop and resistant weeds before seed set with glyphosate.

**Northern wild oat control 2008 and beyond – a commercial perspective**

**By Rob Long BSc Agr, Senior Agronomist B&W Rural**

Wild oat control has become an increasingly difficult exercise in northern NSW in recent years, often due to the increasing prevalence of herbicide resistant wild oats. However in 2008 control problems were compounded by:

- A series of more than 20 consecutive frosts in August
- Late planted (July) crops that required weed management in August/September
- Time and cost pressures prompting more tank-mixes in an attempt to control all weeds in one pass.

As a rule, wild oats become more difficult to control from early August onwards as they rapidly change from vegetative to reproductive growth. In 2008 control levels in June and July were good, yet in August many spray jobs attained less than 60%
control. The series of consecutive heavy frosts during this period also contributed to these poor results and the slower rates of herbicide activity.

**Key commercial considerations for northern wild oat control**

A sound crop rotation is the best way to combat wild oats, as well as many disease and nutrition problems, with the two major non-winter cereal crops being sorghum and chickpeas. Consecutive summer crops is also a consideration where Group A resistance is of concern.

**Sorghum**

Sorghum is our best rotation option to limit Group A herbicide resistance and also reduce the risk of crown rot and other winter cereal stubble diseases. The key benefit aiding wild oats management is the ability to **reduce the wild oat seed-bank numbers during winter fallow phases using non-selective herbicides and other control measures** to provide a break from Group A herbicide usage. Although any ‘break’ can have a positive impact, the biggest benefits come from a well managed summer crop strategy used on a consistent basis.

However there is a management issue to address. Sorghum crops are often being planted earlier (mid September), in an attempt to harvest early. The early harvested sorghum crops enable a longer fallow period, maximising the opportunity to replenish soil moisture for subsequent double-crop chickpeas. The issue here is that soil conditions in September are still cool enough to allow in-crop germinations of wild oats, which are difficult to control. If these wild oats set seed, much of the benefit of the sorghum rotation is negated. In addition this may only allow a one winter break from the use of Group A herbicides. The sorghum double-crop chickpea rotation suits best where wild oat numbers are already well managed and crown rot levels are low to moderate.

**Chickpeas**

The only registered in-crop herbicide options to control wild oats are Group A’s with haloxyfop (eg Verdict®) long the first product of choice. However many haloxyfop jobs have been sub-standard in recent years; despite the resistance tests performed on survivors indicating resistance levels are low. Commercially there appear to be rate responses with higher label rates being used successfully as well as mixtures of Verdict and Select where previous herbicide control problems have been experienced.

Avadex and trifluralin are available for chickpeas and numerous other crops, but growers have been reluctant to adopt these options due to the expense and the requirement for machinery adaptations. Avadex/trifluralin are not stand alone controls and they need to be used in combination with other measures such as spray topping to ensure control of survivors. This is possible in wheat with Mataven® but no current spray top registration exists for chickpeas. **Such an option is desperately needed by the industry.** Also current farming systems are reliant on heavy burdens of stubble which can be counter productive to the most efficacious use of these soil applied products.
The approach in winter cereals

Wheat

Group A, Group B, Group D, Group J and Group Z herbicides all have registrations to control wild oats in wheat. We are encountering wild oat control problems with Group A herbicides such as clodinafop (eg Topik®) and fenoxaprop (eg Wildcat®) on a more regular basis and there has already been an over-reliance on Axial® - a different Group A herbicide sub class - partly because of its efficacy on Phalaris. Commercially we are already seeing Axial control problems and the level of resistance detected in the recent NGA survey was very concerning. Midas®, used on Clearfield JNZ, is an extremely effective herbicide on wild oats and many broadleaves especially black bindweed. Its main limitation is that the variety is a derivative of Janz and carries the same agronomic limitations.

Given the range of effective non Group A options available in wheat it is vitally important that we reduce Group A usage in this crop wherever possible.

Spray topping with Mataven has been used reasonably sparingly but generally with very effective results. Interestingly although there has been cross resistance detected between Group A and Mataven in pot studies, we have not observed similar issues in commercial usage.

Barley

A good competitor with strong early growth rates, however again there is an over-reliance on Axial. Unlike wheat we do not have the luxury of effective Group B or spray top options but this is a crop where Avadex and or trifluralin could have a fit when combined with the competitive nature of barley.

Lessons learnt ‘again’ in 2008

- Don’t plant “dirty” paddocks early (relevant to both winter and summer crops).
- Preferably control the first two germinations with a knockdown pre-plant.
- Try to spray wild oats before August.
- Differentiate between herbicide resistance and just poor control.
- Minimise survivor seed set– they will cost a lot more in the long run than the extra herbicide cost. Be prepared to use multiple control measures.
- Be prepared to spray poorly competitive crops twice e.g. chickpeas, linseed, safflower.
- Conduct more research and rationale on the use of Mataven SST in crops other than wheat.
- Further evaluate non Group A options for barley registrations eg Hussar®
- Try to avoid tank-mixes if at all possible.
- Adopt a long term strategy that reduces the seed-bank.
- Prevention is better than cure. Many resistance management measures are neutral or add a low additional cost. They are ALL cheaper than trying to manage resistance blow outs.
Wild oats herbicide resistance patterns in north-west NSW

By Richard Daniel NGA

It is clear that in recent years there has been increasing difficulty in achieving high levels of control of wild oats, both in broadleaf and cereal crops and with a range of products including different mode of action herbicides. Although environmental conditions and spray application parameters always play an important role, herbicide resistance has been implicated in a lot of situations.

Part of the Northern Grower Alliance approach involves an extensive and broad network of experienced regional consultants and advisors. These advisers are critical in establishing the key research questions and project direction but also in providing an efficient extension pathway. However in this situation they also provided a mechanism to easily sample wild oat populations from a wide range of different situations.

What was done?

A survey was conducted during October 2007 by 34 agronomists who collected seed samples from ~100 separate wild oat populations in an area from Westmar in southern Qld to the Liverpool Plains and west to Walgett and Mungindi. Samples were collected from two different scenarios 1) 'high risk' situations where herbicides had failed in 2007 or in previous years and 2) 'random level' situations where there was no history of any herbicide problem and generally no herbicide was actually applied in 2007. NB Although termed 'random level', these samples were likely to indicate a resistance level LOWER than randomly occurring as a true random pattern would include some ‘high risk’ samples.

All seed samples were sent to Plant Science Consulting for testing in which every sample was exposed to a common set of 9 herbicides as listed below.

<table>
<thead>
<tr>
<th>Product</th>
<th>Herbicide group</th>
<th>Sub group</th>
<th>Weed growth stage at application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triflur X + Avadex Xtra</td>
<td>D</td>
<td>J</td>
<td>Pre emergent</td>
</tr>
<tr>
<td>Wildcat</td>
<td>A</td>
<td>fop</td>
<td>3 leaf</td>
</tr>
<tr>
<td>Topik</td>
<td></td>
<td>den</td>
<td></td>
</tr>
<tr>
<td>Verdict</td>
<td></td>
<td>dim</td>
<td></td>
</tr>
<tr>
<td>Axial</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Select</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Atlantis</td>
<td>B</td>
<td></td>
<td>Stem elongation</td>
</tr>
<tr>
<td>Mataven</td>
<td>Z</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

What was found?
The overall results are shown in figure 1. As expected the results from the two scenarios differed widely in resistance frequency.

Where wild oat samples were collected from high risk situations the patterns of resistance were alarming -
- ~70-80% showed some level of resistance to either Wildcat or Topik.
- ~25-30% had some level of resistance to Verdict, Axial or Mataven
- 16% had some level of resistance to Atlantis
- 7% had some level of resistance to Select

Only the pre emergent treatment of Triflur X and Avadex Xtra provided complete control of all populations. However it is important to note the experimental method for pre emergent activity involved seeds being directly sprayed with the herbicide mixture and then covered with 1 cm of fresh soil. This is to simulate an ‘incorporation by sowing’ approach where seeds are surface germinating. Complete control is very rarely achieved with this approach under real life conditions. Under these conditions, there will always be variability in weed ‘sowing depth’ as well as ‘striping’ in control patterns due to planter soil disturbance and 80-90% levels of control are more common.

Figure 1 – Overall resistance patterns

Where wild oat samples were collected from random level situations the resistance frequencies were much lower but still concerning -
- ~10-20% of populations showed some level of resistance to either Wildcat or Topik.
- Only 1 population showed resistance to Mataven
No resistance was detected to any other herbicide evaluated.

Did the patterns vary by sampled area?

When the survey was conducted it was expected that lower resistance frequencies may have been found in western areas where use of group A herbicides had been less frequent or in areas such as the Liverpool Plains where summer cropping has predominated in recent years with much lower selection pressure on wild oat selective sprays. The results of the high risk samples however showed similar trends across the five broad ‘areas’ sampled particularly for the group A products: Wildcat, Topik, Verdict and Axial.

*Figure 2 – Resistance patterns by ‘area’ sampled (high risk samples)*

Application timing can be critical

Wildcat, Topik and Verdict are all group A herbicides and members of the ‘fop’ sub group. The results in figure 1 highlighted a large difference in result between Wildcat and Topik compared to Verdict. These results suggest that the resistance mechanism is not primarily ‘target site’- where all fops would be expected to show similar resistance patterns but ‘metabolic resistance’ - where the weed has a mechanism to metabolically degrade the herbicide. In these situations it was expected that levels of control may be improved at early weed growth stages. Additional testing of seed samples during August 2008 highlighted this relationship when Topik was used.

*Figure 3 – Impact of application timing on wild oat control*
Clearly when dealing with Group A resistant wild oat populations the most sensible approach is to avoid the use of Group A herbicides completely. However if growers are forced to use these products then it will be important to “go early and go hard”

**Key points**

The last regional survey in the north identified wild oat group A herbicide resistance in ~ 10% of populations. This survey, ~ 5 years later, indicates the level has increased to at least 10-20% of populations but most likely much higher.

Clearly herbicide resistance in wild oats is a widespread issue in the north. Changing management strategies, including the use of summer crop rotations, will be an important component of any long term approach. Seed bank management will also be a key component to limit the magnitude of the problem in individual paddocks. However it is important to remember that no single product or single strategy will provide the long term solution. We need to incorporate a mix of strategies with the ultimate objective being to diminish wild oat seed banks.