How wide spread is resistance?

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Take home messages

- There is a scarcity of information with respect to herbicide resistance surveys in the northern grain region (NR).
- Other 'non-resistance' data such pre-harvest and fallow weed surveys, fallow and in-crop herbicide questionnaires and herbaria records have complimented herbicide resistance specific data.
- The most widespread resistant species are wild oats (Groups A, B and Z) and fleabane (Group M). Awnless barnyard grass and annual ryegrass, both resistant to glyphosate, are found in mainly in the north and south of the northern grain region, respectively. Glyphosate resistant (GR) windmill grass is in the infancy of it's spread, mainly confined on the central west plains.
- Resistance is very patchy. This patchiness could be on a farm to farm, paddock to paddock and within paddock scale.
- Regardless of whether resistance is common in your farming district or not, if you suspect herbicide failure, get your weeds resistance tested.
- Since the discovery of resistance in the mid 1990's in the NR, the number of species affected by resistance and their spread has steadily increased.
- Due to the dot point above, many farmers in the NR are or in the future going to be dealing with summer and winter weeds with various types of resistance. No longer can growers deal with one weed issue separately; they will be forced to solve more complex problems where solving one resistance issue may make another one worse.

Wild oats

Current distribution (regardless of resistance status): Wild oats is one of the most widespread weed species in the NR. Although it not a significant issue in central Queensland, its number steadily increases from the northern downs into NSW.

Surveys: A comprehensive herbicide resistance survey was undertaken by the Northern Grower Alliance (NGA) in 2007 for the central part of the NR. It involved two main sampling criteria;

1. a random background survey and
2. sampling from high risk (to Group A, B or Z herbicides) paddocks.

Approximately 20% of the random survey samples were found to have some resistance to Wildcat®, 10% to Topik® and 4% to Mataven®. Of the 'high risk' samples, between 70 and 75% were deemed to have resistance to Topik or Wildcat, 22 to 30% to Verdict®, Axial® or Mataven, 17% to Atlantis® and 6% to Select®. No samples were found to be resistant to a

trifluralin / Avadex® tank mix. This distribution of resistance was generally common throughout the NGA survey region.

Although the random survey indicates a concerning proportion (22%) of paddocks with some form of resistance, the figures for 2013 should be much worse than this. Since 2007, the incidence of any form of resistance in a paddock should be at least 50%. The reasons for this comment are:

- Six more years of herbicide use should have increased the frequency in the northern region by promoting resistant individuals. The use of selective post-emergence herbicides (Topik and Wildcat) in wheat is the most commonly used practice in the NR.
- Physical sub-sampling in paddocks does not guarantee a resistant patch gets sampled. Therefore random sampling is likely to under-estimate the real problem.
- The NGA survey did not include the southern part of the NR where resistance is likely to be much more common due to the greater frequency of winter cropping.

Of great concern is the number of populations with multiple resistance. More than half the 'high risk' samples had resistance to three different herbicides. In some cases there are populations of wild oats that have resistance to all three modes of actions with selective post-emergence activity. In these cases the production of wheat is seriously under threat. In chickpeas, Group A herbicides are the only post-emergence option. Resistance to Group A herbicides develops quite quickly in wild oats.

Key management issues: As a consequence, the infrequently used pre-emergence chemistries trifluralin, Avadex and now Sakura®, have been promoted to reduce the selection pressure on post-emergence options.

If feasible, summer cropping can be introduced to allow two winter fallows and the use of highly effective knockdown herbicides. Having such a strategy should deplete the wild oat seed bank by 99%.

Herbicide tolerant crops could be introduced into the rotation. Triazine or glyphosate tolerant canola could have a good fit in some circumstances.

In regions where the climate does not allow for canola (western areas) or summer cropping (southern regions), more radical agronomic changes could be considered. Some moderate success has been achieved with wide row crops using cultivation between crop rows. In non Roundup® Ready cotton, glyphosate can be used via a shielded sprayer, or over the top in RR varieties. Glyphosate is unfortunately not registered for inter-row use in crops other than cotton. More competitive crops and planting configurations are changes that do not require too much effort and results in substantially better weed control.

Fleabane

Current distribution (regardless of resistance status): Fleabane has become the most widespread weed species in the NR. This can be attributed to the widespread adoption of minimum or no-till farming and the large number of wind-borne seeds produced.

Surveys: Three comprehensive herbicide resistance surveys were completed in 2010, 2011 and 2012.

The first survey used fleabane seed samples collected in the northwest slopes and plains and the darling downs regions in 2005. It resulted in 6 populations from the Darling Downs and 2 from northern NSW being placed on the glyphosate resistance (GR) register. It was shown that there is a great deal of variation in response to glyphosate depending on the likely history of glyphosate use. Samples collected from paddocks in predominantly non-cropping areas were susceptible to glyphosate, whereas seed sourced from grain growing regions had a better chance of resistance.

In 2011, a national non-cropping survey of glyphosate resistance was completed. It targeted areas such as roadsides, railways, irrigation channels and around buildings such as silos. A further 35 populations from the NR were confirmed as GR. All these were sourced from roadsides, an area commonly treated with glyphosate and hence its abundance in this area. As of January 2013 there are 30 glyphosate resistance cases in NSW and 13 in Qld. Of the 30 cases in NSW, 20 of them came from the Murrumbidgee regions along roadsides. The southern and western parts of the NR are likely to have some GR fleabane, as this area hasn't been properly surveyed, the reliance of glyphosate in fallows and the wind borne seeds should ensure some resistance is present and developing.

The last completed survey in the NR was aimed at trying to find any Group I resistant fleabane. Seed was collected from surviving plants in the summer fallow period. None of these populations were found to have Group I resistance.

Key management issues: A vast array of research has developed useful options to control this weed in fallows and in-crop. At present they are doing a great job at keep fleabane populations to a manageable level. However, almost all of these are reliant upon some Group I chemistry. This understandably will put great selection pressure on Group I herbicides. Other herbicides with good activity on this weed are those from Groups C and H. These need to be researched and registered to ensure diverse options are available.

This weed is particularly susceptible to competition in the seedling stage. It would be prudent to practice integrated weed management by promoting crop competition. Another weakness in the life cycle is the seed's inability to germinate from depths greater than 1 cm. Farming systems that rely upon some cultivation, such as cotton, may find fleabane emergence less frequent.

Despite all efforts aimed at in paddock fleabane control, some seed can be deposited from other areas such as fence lines and farm tracks. Keeping these areas weed free should also compliment in paddock control. NSW DPI has two experiments underway to find suitable treatments in this situation. Previous to 2012, diuron was the best option; however its use as a non-crop option has been halted by the APVMA.

Awnless barnyard grass (BYG)

Current distribution (regardless of resistance status): BYG is reasonably common throughout the NR. There are areas in the NR where its abundance declines eg. the central west plains district. Greatest frequency of BYG is within the Darling Downs and north-west slopes/plains region of NSW.

Surveys: Collaborative survey work between NSW DPI, DAFF Qld and the Northern Grower Alliance (NGA) commenced in late 2011. The aim was to better understand the extent of GR awnless barnyard grass (BYG) in the NR.

Of the 78 samples received, 58% of these (45 samples) were confirmed resistant. These new confirmed cases are now on the Australian Glyphosate Sustainability Working Group (AGSWG) register. Prior to this work the register had 21 confirmed cases, now 58 cases, representing a trebling of the confirmed resistance cases of this species. The location of the GR BYG populations is well spread within the area surveyed. Resistance occurs from Dalby down to Tamworth, with a greater concentration of cases between Goondiwindi and Narrabri. NSW now has 39 confirmed cases and QLD's tally is 18. One population was found in Kununurra in North West Western Australia.

Evidence indicates that some of the plants samples tested are more resistant than the 'resistant standard' collected from a confirmed resistance site (Table 1). This was found after glyphosate rate response experiments. Rates of glyphosate (450g/L) increased from 0.8 to 12.8L/ha with many populations demonstrating survival at the highest rate. The resistant

standard had a 5 to 7 fold level of resistance (from AGSWG register) with 78% control of biomass after 12.8L/ha of glyphosate (450g/L). Note that the biotypes, PLG3, TAP4, GJM2, and JRD1 had % control values generally less than the resistant standard when comparing the 6.4 and 12.8L/ha rates.

Table 1: Percent control of green ABYG biomass 28 DAT for various rates of glyphosate (450g/L)

% control of green biomass (relative to nil rate)							
		Glyphosate (450g/L) rate per hectare					
Biotype	**Location**	**0.0**	**0.8**	**1.6**	**3.2**	**6.4**	**12.8**
Susceptible	Tamworth	0.0	56.5	96.2	100	100	100
Resistant	Bellata	0.0	-1.6	23.4	18.5	49.2	78.0
PMD1	Moree	0.0	-8.0	20.9	42.8	88.7	100
LWN4	Croppa Ck	0	37.4	37.7	81.8	95.8	100
TAP3	Bellata	0	27.8	50.4	37.7	72.3	89.2
PLG3	Boggabilla	0	-104	-151	-162	-17.2	42.6
TAP4	Gurley	0	-103	-6.9	20.8	30.6	44.4
GJM2	Bellata	0	-54	-7.1	21.2	57.6	75.0
JRD1	Westmar	0	-144	-4.2	-15.3	22.9	11.0

This survey will continue into the 2012/13 season. A call for samples from a wider geographical area was made in late 2012 to get samples that better represent the NR. The plan is to demonstrate that GR BYG extends beyond the northwest slopes and plains of NSW and the Darling Downs. Furthermore, NSW DPI data has shown the magnitude of the glyphosate resistance in some populations to be higher than 5 to 7 fold.

The national non-cropping survey also targeted this weed. Areas such as irrigation channels were the main target. Nine samples were collected and three were confirmed resistant to glyphosate. Two of these were sourced from irrigation channels and one from a silo site.

Key management issues: Glyphosate has been the premium herbicide of choice for BYG management in fallows. The lack of many registered pre-emergence herbicides in fallows and the lack of alternative knockdown herbicides give GR BYG an advantage.

Fortunately double knocking has proven to be effective in GR populations. The most common practice is to use a Group A herbicide followed by an application of paraquat. A recent advisor survey by ICAN staff has revealed the use of Group A herbicides in fallows in the NR (Table 2).

Table 2: Breakdown of fallow areas treated with Group A herbicides. Total fallow area represented by respondents was 860,000 hectares.

	Goondi Update		**CQ workshops**		**Central West NSW**		**All**	
Fallow group A use	**Hectares**	**%**	**Hectares**	**%**	**Hectares**	**%**	**Hectares**	**%**
Sequence with paraquat	37237	75	180	32	2388	94	39805	76
Sequence with glyphosate	1316	3	0	0	6	0	1322	3
Sequence with cultivation	6182	13	380	68	6	0	6568	13
Group A alone	985	2	0	0	0	0	985	2
Tank mix glyphosate (no DK)	3150	6.4	0	0	150	6	3300	6
Tank mix with other herb (no DK)	500	1.0	0	0	0	0	500	1
	49370		560		2550		52480	

The 52,480 hectares treated with Group A represents 6% of the total area managed by the surveyed advisors. Most of this use was either followed up by a double knock application of paraquat (76%) or by cultivation (13%). This should ensure that Group A herbicide effectiveness is maintained as long as possible. However, there are some applications that are deemed high risk. These include the single use of Group A herbicides in summer crops such as cotton, mungbeans and sunflowers. Sole use of Group A's in fallows is much worse as there is no crop competition to reduce weed growth from survivors. Mixing or split applications with glyphosate are another high risk practice, particularly on GR plants.

Annual ryegrass

Current distribution (regardless of resistance status): Annual ryegrass (ARG) is mostly distributed in the Liverpool plains, Tamworth/Gunnedah and the central west slopes and plains. An occasional infestation occurs north of Narrabri.

Surveys: Some survey data is available on the presence of in-paddock and non-crop glyphosate resistance ARG for the NR. A register of GR species is available from the Australian Glyphosate Sustainability Working Group (AGSWG) websites: http://glyphosateresistance.org.au/register_summary.html and

http://glyphosateresistance.org.au/GRARG%20Register.pdf

The register contains the various species (ARG, fleabane, BYG and Windmill grass) that have glyphosate resistance, the approximate location, situation, year it was confirmed and the resistance level.

In summary, GR ARG distribution in Australia is best summarised in Table 3.

Table 3: Distribution of GR ARG in Australia by situation and state

Situation		Number of sites	States
Broadacre cropping	Chemical fallow	29	NSW
	Winter grains	99	Vic, SA, WA, NSW
	Summer grains	1	NSW
	Irrigated crops	1	SA
Horticulture	Orchards	5	NSW, SA
	Vine crops	22	SA, WA
	Vegetables	2	Vic
Other	Driveway	4	NSW, Vic, SA, WA
	Fenceline/Crop margin	82	NSW, SA, Vic, WA
	Around buildings	2	NSW
	Irrigation channel	12	NSW, SA, Vic
	Airstrip	1	SA
	Railway	2	WA, NSW
	Roadside	85	SA, NSW, WA

NSW appears as most the frequent state in Table 3 for presence of GR ARG. The two most common situations were chemical fallows and roadsides. The Liverpool plains is the hot spot for GR ARG in chemical fallows, however some outlier areas include Baradine and Moree. No doubt that this register significantly under-estimates the frequency of GR ARG and many anecdotal reports indicate new patches of this weed are present in areas such as the central west slopes and plains. Although the Murrumbidgee region is the hot spot for GR ARG along roadsides and irrigation channels, northern NSW has some representation.

If left unchecked for several years, GR ARG can infiltrate many parts of a catchment. For example, the Liverpool Plains in the late 1990's had many paddocks with extensive GR ARG infestations. Although many years of successful control were completed from the early 2000's, it appears GR ARG can be found in many situations such as waterways, roadsides, around silos, along railways and fence lines. The lesson learnt from this example is to

effectively manage resistant infestations at the early patch stage. This limits the opportunity for the weed to spread seed to these other areas. Consequently, Liverpool Plains farmers are getting excellent results in the paddock but are mindful of the areas that act as a source of resistant plants.

Herbicide resistance in ARG within the NR is not purely glyphosate resistance. It can exist in various forms. Data from Charles Sturt Universities testing service indicates within NSW and southern parts of Australia that ARG resistance can exist as Group A, B, C, D, L and M resistance. The data is not broken down to the region level so getting a handle on other forms of resistance in the NR is not possible. Despite this, the report indicates that some samples had resistance to four herbicide groups. The most common level of multiple resistances was two herbicide groups (66% of samples). Resistance to Group A (fops, dims and dens) was common (~70%) with a lower frequency for resistance to clethodim (~ 25%). This means that clethodim is usually the last group A herbicide that develops resistance and herbicides such as diclofop and tralkoxydim are likely to fail initially.

The same survey has shown that resistance to Group B herbicides is very frequent. Between 50 and 100% of samples tested were resistant to group B sub-chemistries of sulfonyl ureas (eg. Logran®, Glean®, Atlantis®, Hussar®) and imidazolinones (eg. Intervix® and Crusader®).

An occasional sample was confirmed resistant to herbicide groups C (atrazine), D (trifluralin) and L (paraquat/diquat). Two and five percent of samples tested were resistant to atrazine and trifluralin, respectively. One sample was confirmed resistant to paraquat/diquat.

It is likely that Group A and B resistance is scattered in the central west parts of NSW and would become less frequent further north or east. This is probably directly correlated to the frequency of winter cropping, hence history of group A and B use in the central west compared to other NR districts.

Key management issues: There are several management issues for ARG. Issues include:

- Manage resistance early in the patch stage
- Management becomes more difficult with multiple resistance.
- Double knocking with the paraquat 2nd knock is an effective tactic, however carefully monitor for paraquat resistance.
- The central west region will be under great pressure from ARG. Future trends indicate that multiple resistant ARG will become an issue. The use of imidazolinone, atrazine and glyphosate tolerant crops will give some relief in the interim; however there is confirmed resistance to all these groups in NSW and the frequency of resistant populations will increase. Non-chemical tactics will have to be used to slow this trend.
- Non-chemical management options such as windrow burning, chaff carts or seed destructors will have a role in the central west.
- Keep fence lines and irrigation channels free of weeds. Experience from southern parts of Australia suggests many GR cases originate from such areas.

Windmill grass

Current distribution (regardless of resistance status): Windmill grass occurs throughout the NR with most abundance around the central west district. It grows more frequently on lighter textured soils.

Surveys: The AGSWG website is the only source of information about glyphosate resistance in this species. Currently there are three cases of GR windmill grass in NSW. All these are located west of Dubbo, two in fallow paddocks and one along a roadside. Other GR windmill grass infestations occur in Victoria (6 cases on roadsides) and one in Western Australia (roadside).

An ICAN survey conducted in 2011/12 found that windmill grass was the most important weed targeted in summer fallow with the central west region. It did not rate highly as a target weed in central Queensland or northern NSW/SE Qld.

Key management issues: Like BYG, windmill grass management has essentially been driven by glyphosate. Double knocking with quizalofop followed by paraquat offers some control, but plants must be 3-leaf to mid tillering and not moisture stressed. (See Permit PER13460 for use in NSW). Apart from this control options are limited to cultivation.

Research in the future will be directed at finding effective pre-emergence control as controlling larger plants with herbicides is difficult.

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