The Northern Grains Region: its unique herbicide resistance challenges

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Summary Reports of unique herbicide resistance cases in the northern grains region have increased in recent years. Glyphosate resistance is the main issue. Other cases of include resistance to synthetic auxins ALS inhibitors and ACCase inhibitors. This has serious implications for zero or minimum till fallow farming practices and glyphosate tolerant crops in this region.

To complicate the matter, the northern grains region is extremely variable; having a diverse range of cropping rotations, a large range of weed species, both summer and winter active and many of these shed seed prior to harvest limiting seed capture/destruction technologies.

Keywords Glyphosate, resistance, fallow, herbicide tolerant crops, integrated management.

INTRODUCTION

The northern grains region (NR) is extensive and diverse. It is broadly defined as the area between Emerald and Dubbo (north to south) and Toowoomba to Cobar (east to west). Rainfall is generally summer dominant and high yield potentials are linked to stored moisture in the fallow phase. Cotton is another crop that can be grown in place of grains. Both cotton and fallows depend on the effective use of glyphosate. Cropping choice is significantly greater than other cropping regions in Australia. Crops such as sorghum, sunflowers, a wide range of winter and summer pulses, winter cereals and cotton are the major choices. Although this cropping diversity would infer good crop and herbicide mode-of-action rotation, glyphosate resistance has developed steadily.

Weeds, such as annual ryegrass (*Lolium rigidum* Gaudin), awnless barnyard grass (*Echinchloa colona* (L.) Link), flaxleaf fleabane (*Conyza bonarensis* (L.) Cronquist) and windmill grass (*Chloris truncata* R.Br), are confirmed as glyphosate resistant and are well distributed in parts of the NR (Cook 2014). Isolated infestations of glyphosate resistant common sowthistle (*Sonchus oleraceus* L) and liverseed grass (*Urochloa panicoides* P. Beauv) are also present.

It is noteworthy that this region has many cases of resistance to other modes-of-action. Weeds such as annual ryegrass and wild oats (*Avena* sp.) are noted to have resistance to three different modes-of-action. A variety of weeds have become resistant to ALS inhibitors, particularly the brassicaceous weeds (Heap 2014). One case of synthetic auxin resistance has recently been discovered for wild radish (*Raphanus raphanistrum* L.).

This contrasts to the to the other grain regions which are broadly termed the southern and western zones. These regions are dominated by winter cropping and in-crop rainfall represents a large majority of their annual rainfall. Rainfall in the fallow period is light and infrequent and may require the occasional application of glyphosate to control weeds. Often crops are dry-sown thus negating a pre-sowing knockdown application of glyphosate.

Annual ryegrass, wild radish and wild oats are the three dominant species. Control of these weeds was previously and solely based on in-crop herbicides. Due to over-reliance of these in-crop herbicides, multiple resistance to several modes-of-action has occurred in each species. Harvest management of weed seed has significantly improved weed control. Wild radish and annual ryegrass retain their seed at maturity allowing larger proportions to be collected during the harvesting process. However, this new system of control is still dependent on herbicides, especially pre- or early post-emergence options.

Glyphosate resistance is present in these zones. Its development is much slower than the NR, but is accelerated in areas with high frequency glyphosate use. These areas include fence lines and roadsides, particularly for annual ryegrass. In these areas there is no crop competition and thus weeds capable of surviving glyphosate are able to produce large quantities of seed.

In summary, the NR has more weed species to contend with due to its extensive size and contrasting environments. Many of its weeds do not retain their seeds at maturity, making seed capture tactics less suitable. Furthermore as glyphosate resistance cases increase, the appeal to solve these problems with alternative herbicides remains. The challenge is to develop more robust management systems in the NR that incorporates non-chemical tactics, similar to is being done in other grain growing regions of Australia.

CURRENT CASES OF GLYPHOSATE RESISTANCE

The first case of glyphosate resistance was confirmed in 1997 on annual ryegrass (Heap 2014). Continuous sorghum winter fallow rotations lead to this first case. From 2007, a steady number of unique glyphosate resistance cases were reported for the northern region (Table 1). This observation is a direct consequence of the higher reliance on glyphosate in the NR.

A detailed understanding of the distribution these glyphosate resistant weeds is patchy. Cook (2013) reported on the distribution of herbicide resistant weeds for this region. Data gathered was a compilation of various smaller surveys. In summary, annual ryegrass is confined to the south west portion of the region and awnless barnyard grass is centered on the NSW/Queensland border districts. Fleabane is likely to be widespread due to its wind borne seed and liverseed grass is limited to the North West district of NSW. Sowthistle appears mainly confined to the Liverpool Plains district of NSW as a result of recent survey data (not published). Windmill grass is located in the Central West region of NSW.

Furthermore anecdotal evidence notes that sweet summer grass (*Brachiaria eruciformis* (Sm.) Griseb.) in Central Queensland survived robust rates of glyphosate. This will be investigated by the Australian Glyphosate Sustainability Working Group (AGSWG).

Another weed that is tolerant of glyphosate is feathertop Rhodes grass (*Chloris virgata* Sw.). This weed is causing significant problems in Queensland and is steadily moving into NSW.

Impacts are far reaching Glyphosate resistant weeds are mostly observed in fallow paddocks as these areas are treated generally with glyphosate. However, these weeds can cause problems in other areas where glyphosate application is the common practice. These could include; fence lines, roadsides, irrigation channels and in fields planted with glyphosate tolerant crops.

Preston (2014) maintains a national glyphosate resistance register and notes the situation where a glyphosate resistant weed is found. As seen in Table 2, management of glyphosate resistant weeds needs to extend beyond the farm paddock.

Table 1. New glyphosate resistance cases reported in Australia (year of discovery).

GRDC Region		
Northern	Southern	Western
Annual ryegrass (1997)	Annual ryegrass (1996)	Annual ryegrass (2003)
Awnless barnyard grass (2007)	Brome grass (2011)	Awnless barnyard grass (2010)
Liverseed grass (2008)	Fleabane (2011)	Wild radish (2010)
Windmill grass (2010)	Windmill grass (2012)	Windmill grass (2012)
Fleabane (2010)		
Sowthistle (2014)		

Souce: International survey of herbicide resistant weeds (Heap 2014) and Australian Glyphosate Resistance Register (Preston 2014).

Table 2. Glyphosate resistance in non-cropping areas of NSW and Queensland (Preston 2014).

Weed	Situation(s)
Annual ryegrass	Fence line, around buildings, irrigation channel, railway, roadside
Fleabane	Around buildings, irrigation channel, railway, roadside
Barnyard grass	Silo, irrigation channel
Windmill grass	Roadside

MANAGEMENT OF THESE WEEDS

Despite the recent cases of glyphosate resistant weeds in the northern region, alternative management of these weeds appears to have kept them at low densities. This change of management is heavily reliant on changing herbicide mode-of-action and an occasional use of cultivation.

Managers of weeds in fallow are gradually adopting pre-emergence herbicides and substituting a non-glyphosate follow-up spray to control survivors. For example, resistant grass weeds are controlled with either a photosystem II inhibitor or an imidazolinone as the pre-emergent option. Survivors are double knocked with ACCase inhibitors then followed by a photosystem I inhibitor.

Glyphosate tolerant crops, such as cotton, are threatened by these new glyphosate resistant species. Occasionally pre-emergence herbicides or inter-row cultivation are required to combat this threat.

The role of classic integrated weed management in the NR is not yet fully utilised. Weed seed post-harvest management is at the early adoptive phase in the south-west portion of the NR. Generally crops are very competitive but are sown on wider than recommended rows in western drier districts. Non-crop management of weeds is irregular and managers of these non-agricultural areas (roadsides) seem slow to make any changes to their control programs.

Widderick *et al.* (2014) has researched persistence of awnless barnyard grass under various cropping systems. The same paper also reported the effects of cultivation on various NR weed seed banks. Barnyard grass appears to have short-lived seed in the soil with 1% of seed viable after three years. The effects of cultivation were variable with one-way disc being the most consistent at reducing weed emergence. Rainfall patterns seem the likely cause of variation in emergence. In some cases cultivation did elevate weed emergence and this could be used to deplete the seed bank instead of burying viable seed.

CURRENT RESEARCH

Development of new solutions to current weed management problems is a joint effort. The Grain Research and Development Corporation (GRDC) have funded scientists from both NSW and Queensland departments along with researchers from universities and grower solution groups. Furthermore, chemical companies are investing resources into improved weed management.

Widderick *et al.* (2014) best elaborates on some of the NR research initiatives. However, in summary the broader research agenda for the next five to ten years is:

- More ecological work: effects of cultivation and seed bank decline.
- Development of new active ingredients.
- Finding new uses for existing active ingredients.
- Registration of more pre-emergence herbicides, especially in fallow situations.
- Expanding optical sensing technology label claims (e.g. WeedSeeker and Weedit technology).
- Novel ways making double knocking more economical.
- Economic evaluation of some integrated weed management tactics.
- Validating weed seed destruction techniques.
- Investigating the feasibility of robotics for fallow and inter-row weed control.
- Developing solutions for non-crop management of resist weeds.
- Patch management of weeds and to demonstrate the importance of small scale eradication.

FUTURE CHALLENGES

Despite the efforts of various researchers, challenges remain. The rate of glyphosate resistance development is alarming. A consequence of this is a shift to alternative options, mainly chemical solutions. A proactive approach is needed to pre-empt potential new problems. This requires a detailed knowledge of the factors that lead to herbicide resistance.

In a recent workshop of leading agronomists and consultants, herbicide resistance issues that may face the NR by 2024 were discussed. Such predictive analyses were based on the following factors:

- Resistance gene frequencies for certain mode-of-actions.
- Frequency of herbicide use.
- Summer/winter cropping options.
- Use of double knocking.
- Resistance from non-crop areas.
- Wind blown seed.
- Cultivation frequency.
- Herbicides used in tank mixing.
- Pre- or post-em herbicides (post-emergence more likely to develop resistance).
- Ability to control resistant survivors.
- Case studies of similar weeds in other parts of Australia.
- Likelihood of other mode-of actions being used on weed species.
- Advances in non-chemical control tactics.

It was predicted that the current glyphosate resistant grass weeds are likely to develop some resistance to the ACCase or photosystem I herbicides. Other species of grasses may develop glyphosate resistance as is likely for sweet summer grass. Broad leaf weeds, fleabane and sowthistle may develop resistance to synthetic auxin mode-of-action herbicides due to over reliance. Other brassicaceous weeds may develop ALS inhibitor resistance, as similar species already have that characteristic due to frequent in-crop use. There is likely to be other weed species, not considered, that will join the herbicide resistance register.

History has shown that despite discovery of new herbicide resistance cases, on most occasions the spread of these weeds on a regional scale continues. However, the density of weeds may actually decline with the inclusion of alternative control strategies. Spread may arise from natural dispersal of seed (wind, floods and via animals), poor hygiene practices or development of the resistance in situ. Therefore, existing cases of resistance are likely to spread further into new areas within the NR. As a consequence, certain areas are likely to develop on farm but receive new cases of resistance developed elsewhere.

DISCUSSION

The northern grains region has markedly unique challenges. Herbicide resistance can express itself in many forms and within many cropping systems. Not only does resistance occur in both summer and winter active species, these species are sometimes found on the same property. Management then becomes increasingly complicated and costly as a solution to one resistance issue may exacerbate the other. Currently these problems are generally being resolved with alternative herbicide based solutions. The longevity of these solutions is a concern as non-chemical options are restricted to cultivation and/or crop competition. There is some scope for weed seed harvest tactics however these become more feasible in the southern parts of the NR.

Ultimately the question must be posed to the industry: Can we find sustainable solutions to these challenges? With a deficiency of widely adopted non-chemical control options in the NR, there is realisation amongst researchers that the NR has much to lose. There are two sub-regional examples to highlight this looming threat.

The first example is from the central west slopes and plains district of NSW where annual ryegrass and wild oats are reported to have resistance to three difference mode-of-action herbicides. In addition, barnyard grass, fleabane and windmill grass have developed glyphosate resistance in this region. Synthetic auxin resistant wild radish has emerged. Slowing the progression of herbicide resistant annual ryegrass and wild radish may be alleviated with harvest seed management. Likewise the Liverpool Plains district has similar weed issues. Instead of auxin resistant wild radish they are the regional hot-spot for glyphosate resistant common sowthistle and have a new confirmed case of glyphosate resistant liverseed grass.

Hot-spots of resistance in these regions may serve as excellent case studies. It would test the managerial capacity of agronomists and the alternative measures required to control a range of resistant weed species. The need of cultivation to control these multiple species might be an option, possibly at the expense of fallow soil moisture benefits and subsequent crop yields.

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