Managing herbicide resistance in Southern Australian farming systems using Roundup Ready® canola

James E. Neilsen and Ian N. Taylor
Monsanto Australia, Level 12, 600 St Kilda Road, Melbourne, Vic 3004, Australia
Corresponding author: james.eric.neilsen@monsanto.com

Summary In the 2009 season almost 73% of paddocks in which Roundup Ready® canola was grown were reported to have resistance to at least one herbicide mode of action (MOA) with 42% being resistant to at least two MOA. Experimental results showed 95% control of Group B resistant annual ryegrass (*Lolium rigidum*) populations using Roundup Ready® herbicide in canola cropping situations. A potential threat with the introduction of Roundup Ready canola is for increased glyphosate resistance. Practices that are not based on glyphosate are required in the year following Roundup Ready canola with the number of these depending on the risk profile of the paddock in which the Roundup Ready canola is grown. This is being implemented as part of the Roundup Ready canola resistance management plan, which mandates that growers implement IWM. This plan provides growers with flexibility in their management options, whilst preserving the effectiveness of glyphosate and other herbicides in the farming system.

Keywords Glyphosate, herbicide tolerant crops, herbicide resistance.

INTRODUCTION

Canola is primarily used in the Australian cereal cropping system as a disease break and for the control of weeds. A survey by Angus (2001) concluded that wheat grown after canola had a 20% yield increase when compared with back to back wheat crops. Carmody and Pritchard (2009) reported that weed control was the most important factor in growers electing to grow canola in the crop rotation in Western Australia.

With the introduction of Roundup Ready® crops into the Australian cropping system (cotton in 2002 and canola in 2008) there has been an increased focus on the sustainability of glyphosate in these cropping systems. However, the benefits of managing other MOA herbicide resistance have been largely overlooked. The incidence of herbicide resistance in the Southern Australian cropping system is high, with Broster and Pratley (2006) reporting the results of commercial resistance testing showing that in annual ryegrass (*Lolium rigidum*) 72% of samples tested were resistant to Group A1 herbicides and 40% were resistant to Group B herbicides while the resistance to glyphosate was only 0.4%. Hashem *et al*. (2001) and Heap (2010) have also reported triazine (Group C) resistance in populations of wild radish (*Raphanus raphanistrum*) and annual ryegrass in the Australian canola growing regions. Wild radish resistance to triazines has occurred where both lupins and triazine tolerant canola have been grown in rotations and both crops received high application rates of these triazines (Norton 2003). Triazine tolerant canola is the most widely-grown canola system in Australia comprising more than 60% of the national crop (Norton and Roush 2007).

A survey of paddocks growing Roundup Ready canola was conducted to determine what weed species were being targeted using the system and the level of existing herbicide resistance present in those populations. In addition, an experiment was conducted to study the control of high populations of Group B herbicide resistant ryegrass with Roundup Ready herbicide.

MATERIALS AND METHODS

Survey of resistance The data were collected as part of the Resistance Management Plan for all Roundup Ready canola growers in the 2009 canola season. For every paddock planted to Roundup Ready canola (n = 743), growers recorded how many modes of herbicide resistance they had in the annual ryegrass population in that paddock.

Resistant ryegrass control trial A trial to evaluate weed control in the three different herbicide tolerant canola systems commercially available in Australia (Roundup Ready, Clearfield® and triazine tolerant) was conducted at Wallendbeen NSW during the 2009 canola season. The trial was conducted in a paddock with a pre-existing ryegrass population of approximately 500 plants m^{-2}. Herbicide resistance testing of the pre-existing ryegrass population prior to undertaking the experiment indicated that the ryegrass population was resistant to Group B herbicides.

Representative varieties for the region from all herbicide tolerant canola systems were selected with three Roundup Ready varieties (Hyola 601RR, 46Y20 and GT61), two Clearfield varieties (46Y78 CL and Hyola 571 CL) and two triazine tolerant varieties

(Marlin and Tawriffic) being grown in 6 × 10 m plots with four replicates in a randomised complete block design. The canola was planted into moist soil on 29 May and harvested on 23 November 2009.

Treflan (trifluralin, 480 g a.i. L^{-1}) at 2.1 L ha^{-1} was applied pre-plant to all plots to reduce weed pressure. The Roundup Ready system received two applications of Roundup Ready herbicide (glyphosate mono ammonium salt, 690 g a.i. kg^{-1}) at 0.9 kg ha^{-1}, the first at the 2-leaf stage followed by an application at the 6-leaf stage. Clearfield varieties received Intervix (imazamox, 33 g a.i. L^{-1} and imazapyr 15 g a.i. L^{-1}) at 600 mL ha^{-1} + Hasten adjuvant at 0.5%) + Select (clethodim, 240 g a.i. L^{-1}) at 250 mL ha^{-1} at the 2-leaf stage. The triazine tolerant varieties received a pre sowing application of simazine (Simazine 900, 900 g a.i. L^{-1}) at 1.1 kg ha^{-1} followed by atrazine (Atrazine 900, 900 g a.i. L^{-1}) at 1.1 kg ha^{-1} + Hasten at 0.5%) + Select at 250 mL ha^{-1} and 1.0% Liase additive) at the 2-leaf stage. Weed control was assessed at the end of the season in all plots by visual comparison to an untreated control by a single assessor. Data presented are the mean of 4 replicates.

RESULTS AND DISCUSSION

Survey In 2009 Roundup Ready canola was grown in over 600 paddocks (42,000 ha) by approximately 300 growers in New South Wales and Victoria. A survey of these growers indicated that in over 90% of cases the primary weed targeted in their canola crop was annual ryegrass (Figure 1). Herbicide resistance in annual ryegrass in Southern and Western Australia has previously been attributed to at least seven different herbicide mode of action groups (Heap 2010). Wild radish was the next most prevalent weed species targeted in around 30% of paddocks. This weed has the potential to have a large impact on the performance and economics of growing canola. Jones *et al*. (2005) conducted analyses of the annual costs of weeds in winter crops across Australia and showed that the most economically important weeds were annual ryegrass, wild oats and wild radish. Stanton *et al*. (2001) reported that for annual ryegrass control, early post-emergence glyphosate application in Roundup Ready canola provided more effective control than conventional or triazine tolerant systems.

Figure 2 shows the pre-existing level of herbicide resistance in Roundup Ready canola paddocks. Thirty percent of paddocks contained annual ryegrass resistant to one herbicide MOA, a further 40% of paddocks had resistance to two MOA; and 2% had resistance to three MOA. Although the data do not show which specific MOA the levels of resistance correspond to, they provide information on the underlying level of resistance growers in the Southern Australian cropping system experience and why integrated weed management (IWM) is critical to their ability to continue to crop productively. IWM strategies have to be developed on a case-by-case basis, considering the nature of the herbicide, crop agronomics, biology of target weed species and available alternatives for control. Powles (2008) stated that maintaining diversity in weed control is crucial for glyphosate to be sustainable and that glyphosate is essential for present and future world food production.

In contrast to the experience in North America where glyphosate tolerant crops have become the main component of the rotation (Powles 2008), Roundup Ready canola has been introduced as only one component of the crop rotation. Canola is currently sown once in every 3 or 4 years, therefore the potential development of glyphosate resistance is reduced, as growers rotate crops and use herbicides with different MOA within the crop rotation.

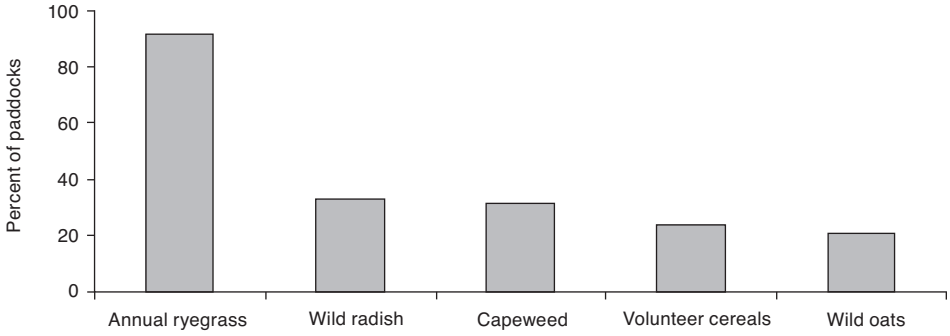

Figure 1. Target weed species in 2009 season Roundup Ready canola paddocks.

Resistance management Monsanto is committed to maintaining diversity in weed control and maximising the value of Roundup Ready traits and Roundup herbicide in the Australian agricultural sector, through the implementation of resistance management plans.

The Resistance Management Plan for Roundup Ready canola utilises the Paddock Risk Assessment and Management Option Guide (PRAMOG®) as a step-by-step risk assessment process on a paddock by paddock basis. The three steps in PRAMOG are:

- An evaluation of glyphosate use history in the paddock
- A determination of glyphosate resistance 'risk profile'
- A choice of management actions based on 'risk status'.

The glyphosate resistance risk profile is calculated from the number of applications of glyphosate to a ryegrass population, which determines the selection pressure applied for glyphosate resistance. The intensity of selection pressure is determined by whatever alternative management practices are incorporated into the cropping system (e.g. a glyphosate application followed by full-cut cultivation provides less intensive selection pressure than a no-till glyphosate application). This is combined with the number of herbicide modes of action to which the ryegrass population in the paddock is resistant. The resulting herbicide resistance status of a paddock reflects the consequences of previous management practices and is an indicator of the resistance pressure that has already been placed on glyphosate.

The resulting risk profile mandates that growers implement either one or two non-glyphosate based management practices in the year following Roundup Ready canola, and if the risk is high it is recommended that farmers do not use glyphosate in the year following Roundup Ready canola.

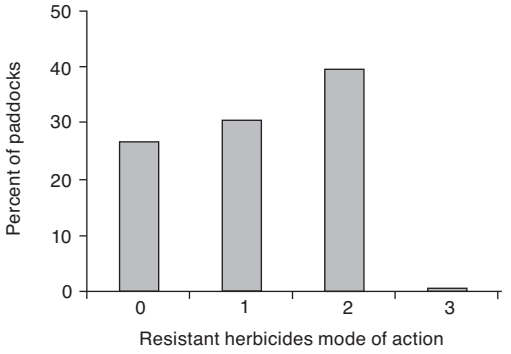

Figure 2. Percentage of 2009 Roundup Ready canola of paddocks with pre-existing herbicide resistance.

Resistant ryegrass control trial Experimental work has shown the level of weed control between the herbicide tolerant systems. The Roundup Ready system provided 95% control of annual ryegrass and the triazine tolerant 91% control (Figure 3). Weed control in the Clearfield system was significantly less than the other systems and was influenced by the presence of the Group B resistant ryegrass, despite the application of a grass selective herbicide (Group A herbicide) to control the resistant ryegrass.

Roundup Ready herbicide controls weeds with established resistance to other groups of herbicides. Strategic use of Roundup Ready herbicide will allow growers to rotate away from the high risk herbicide groups and the ability to control these resistant weeds in the canola rotation reduces seed set thereby reducing

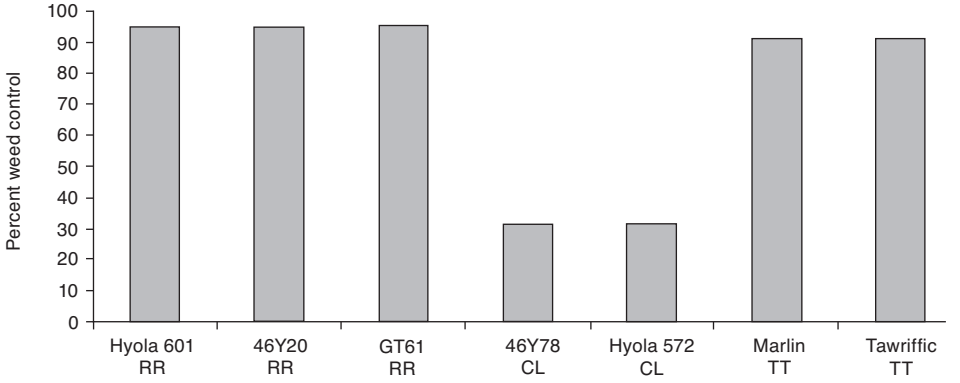

Figure 3. Weed control (%) in the three herbicide-tolerant canola systems.

the weed seed bank. Roundup Ready canola cropping supports the sustainable use of the other herbicides, including Group B and C herbicides for crops such as lupins, other pulse crops and canola.

REFERENCES

Angus, J.F., Kirkegaard, J.A. and Peoples, M.B. (2001). Rotation, sequence and phase: research on crop and pasture systems. Proceedings of 10th Australian Agronomy Conference, Hobart, February 2001 (http://www.regional.org.au/au/asa/2001/plenary/4/angus.htm).

Broster, J.C. and Pratley, J.E. (2006). A decade of monitoring herbicide resistance in *Lolium rigidum* in Australia. *Australian Journal of Experimental Agriculture* 46, 1151-60.

Carmody, P. and Pritchard, I. (2009). Attitudes of Western Australian wheatbelt growers to break crops. Crop Updates. Perth, Western Australia. pp. 20-5. Department of Agriculture and Food Western Australia.

Hashem, A., Dhammu, H.S., Powles, S.B., Bowran, D.G., Piper, T.J. and Cheam, A.H. (2001). Triazine resistance in a biotype of wild radish (*Raphanus raphanistrum*) in Australia. *Weed Technology* 15, 636-41.

Heap, I.M. (2010). International survey of herbicide resistant weeds online. Weed Science Society of America (http://www.weedscience.org/In.asp. accessed 31/01/2010).

Jones, R.E., Vere, D.T., Alemseged Y. and Medd, R.W. (2005). Estimating the economic cost of weeds in Australian annual winter crops. *Agricultural Economics* 32 (3), 253-65.

Norton, R. (2003). Conservations farming systems and canola. University of Melbourne. 35 pp.

Norton, R.M. and Roush, R.T. (2007). Canola and Australian farming systems, 10 pp. The University of Melbourne.

Powles, S.B. (2008). Evolved glyphosate-resistant weeds around the world: lessons to be learnt. *Pest Management Science* 64, 360-5.

Stanton, R., Pratley, J. and Hudson, D. (2001). Annual ryegrass control in conventional and herbicide tolerant canola. Proceedings of the 10th Australian Agronomy Conference, Hobart, February 2001 (http://www.regional.org.au/au/asa/2001/p/12/stanton.htm).