Crop Updates 2010 - Genetically Modified Crops, Nutrition and Soils

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Evaluation of the environmental and economic impact of Roundup Ready® canola in the Western Australian crop production system

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KEY MESSAGES

We report a desktop analysis of some of the potential economic and environmental impacts at the farm level of Roundup Ready® canola in Western Australia. The analysis considered projected yields and costs, patterns of herbicide use and fuel use (and associated greenhouse gas production).

The results showed that:

- the profitability of Roundup Ready canola was similar to that of triazine tolerant canola, the canola system most commonly used in Western Australia
- the estimated environmental impact of Roundup Ready canola was less than half that of triazine tolerant canola
- the estimated fuel use and related greenhouse gas production for Roundup Ready canola were slightly lower (5–6 per cent and 1–2 per cent respectively) than triazine tolerant canola
- greater profitability of Roundup Ready over triazine tolerant canola is dependent on yield differences of over 15 per cent (the upper end of the observed range) in order to offset the trait fee.

Overall, this analysis suggests that Roundup Ready canola could be as profitable or more profitable than triazine tolerant canola with a reduced environmental impact and slightly reduced fuel use. This suggests that it could be particularly useful in situations where the management of weeds is a concern. It is important to manage any implementation of the technology as part of an integrated weed management programme to ensure that it will remain a viable tool in the future.

AIMS

The aim of this ex-ante, desktop study was to estimate some of the potential economic and environmental impacts at the farm level of Roundup Ready canola in Western Australia compared with other canola production systems (triazine tolerant, Clearfield® and conventional).

METHOD

A summary of the methods is presented below. A complete description may be found elsewhere (Fisher and Tozer 2009).

Economic analysis

The economic analysis consisted of a partial budget for a ‘typical’ farm size and rotation for cropping businesses in Western Australia. Cropping systems were modelled for three rainfall zones; low (250–325 mm), medium (325–450 mm) and medium-high (450–750 mm). It was assumed that the farm system, in which the canola is incorporated, is 3,200 ha, of which 70 per cent is in crop at any one time. The remaining 30 per cent is in fallow or non-arable. For simplicity three crops are included in the rotation, cereal, canola, and lupin. In the sample systems used in the analysis, the level of canola and lupin was 10 per cent or 20 per cent of the area cropped, with the remainder of the cropped area as cereal crops. The gross margin was fixed for lupins at $70/ha. In the medium and medium-high rainfall zones the average wheat yield was 3t/ha with a standard deviation of 0.56 t/ha. In the low rainfall zone wheat yield was 1.5 t/ha with a standard deviation of 0.25 t/ha. The wheat price was based on the average real price over the past ten years. We used yield distributions of canola from commercial trial data from other regions of Australia (New South Wales and Victoria). The data were modified to suit the three different cropping zones in Western Australia by using five-year
averages from the top 25 per cent of growers in each of the three rainfall zones yields (Farmanco 2008; Planfarm: BankWest 2009) as the mean yield of Roundup Ready Canola and then applying the relative average yields and distributions for the four canola systems from the trial data from NSW and Victoria. On this basis, the Roundup Ready canola yield was assumed to be 0.8 t/ha for the low rainfall zone, 1.2 t/ha for the medium rainfall zone and 1.5 t/ha for the medium-high rainfall zone. Rates of application and types of fertiliser and agri-chemicals were derived from practices and farm plans common in each of the production zones.

Gross margins and total gross margin models were developed in MS Excel and stochastic simulation models, using Crystal Ball 2000, were run over 10 000 iterations to measure the mean and standard deviation of the different production systems and crop rotations.

**Environmental analysis**

Herbicide applications from the commercial trials in NSW and Victoria were modified to represent WA production and were then used to estimate farm-level environmental impacts based on an environmental impact quotient (EIQ) field rating and farm fuel use. We used the EIQ developed by Kovach et al. (1992), which estimates the combined risk to farm workers, consumers, and the environment for a specific pesticide. An estimated Environmental Impact (EI) for each canola system was calculated using the EIQ field rating for each herbicide, which is the product of the EIQ and the application rate on an active ingredient basis. The EI was determined as the sum of the EIQ field ratings for each herbicide regime for each system. An average for each system was also calculated.

The Farm Fuel Calculator (Bowling et al. 2008) was used to estimate the fuel use and greenhouse gas production for each canola production system based on the number of herbicide applications for each. Values were calculated for the canola phase only and were based on a soil with 8 per cent clay content, default settings for machinery power (105 kW pre-emergent, 150 kW post-emergent and 250 kW seeding), speed (28 Km/h) and boom size (33.5 m) and a direct harvest.

**RESULTS**

**Economic analysis**

Overall the results of the economic analysis reflected the variation in the yield data with high coefficients of variation for all of the systems (Table 1). In the medium and medium-high rainfall zones Roundup Ready canola generated numerically higher total gross margins than the triazine tolerant system, while those in the low rainfall zone were slightly lower. However, there was no significant difference between the triazine tolerant and Roundup Ready canola in economic terms in any of the rainfall zones, for either the 10 per cent or 20 per cent canola models. The Clearfield technology had numerically higher total gross margins than the other three canola systems, due to the higher yields of Clearfield canola in the trial data used in this study. The gross margin of the conventional system was numerically higher than that of either the triazine tolerant or Roundup Ready canola; however the variance of the conventional system was also higher than any of the other systems, including Clearfield (as indicated by the coefficients of variation). This may have been as a result of the small number of observations for the conventional system in the trial data. In summary, taking account of the coefficient of variation, the returns of the four systems were similar (Table 1).

**Environmental analysis**

The estimated EI of the triazine tolerant canola system was on average one and a half times more than Roundup Ready canola and more than double that of the other two systems. The conventional canola system had the lowest estimated EI, being on average 84 per cent of the Clearfield and 41 per cent of the Roundup Ready systems (Table 2).

With effective weed control from one to three spray operations, Roundup Ready canola required slightly less fuel and produced slightly less carbon emissions than the other systems (data not shown). The estimated fuel use of Roundup Ready canola was on average 5 per cent lower than the triazine tolerant canola systems. The Roundup Ready® system also used less fuel than the conventional system (6 per cent) and the Clearfield system (5 per cent).
DISCUSSION

Roundup Ready canola compared positively to triazine tolerant canola in WA farming systems. From an economic perspective Roundup Ready canola was a competitive enterprise. In gross margin terms Roundup Ready canola was found to be comparable to triazine tolerant canola (and also to conventional and Clearfield canola). The environmental analysis showed that Roundup Ready canola

Table 1 Summary of total gross margin (mean and coefficient of variation, CV) for different levels of canola in the crop rotation (10% and 20%) and different yields due to rainfall zone. The chief basis of comparison is triazine tolerant canola as it is the majority of canola currently grown in Western Australia.

<table>
<thead>
<tr>
<th>Rotation</th>
<th>System: Triazine tolerant</th>
<th>Roundup ready</th>
<th>Clearfield</th>
<th>Conventional</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Low Rainfall Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% canola, 0.8 t/ha</td>
<td>mean $160 184</td>
<td>$159 957</td>
<td>$168 075</td>
<td>$165 565</td>
</tr>
<tr>
<td>CV (%)</td>
<td>48.0</td>
<td>49.0</td>
<td>47.5</td>
<td>53.7</td>
</tr>
<tr>
<td>20% canola, 0.8 t/ha</td>
<td>mean $143 707</td>
<td>$143 254</td>
<td>$159 489</td>
<td>$154 470</td>
</tr>
<tr>
<td>CV (%)</td>
<td>67.9</td>
<td>70.9</td>
<td>67.1</td>
<td>85.3</td>
</tr>
<tr>
<td></td>
<td>Medium Rainfall Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% canola, 1.2 t/ha</td>
<td>mean $390 118</td>
<td>$397 066</td>
<td>$414 600</td>
<td>$406 325</td>
</tr>
<tr>
<td>CV (%)</td>
<td>45.7</td>
<td>46.0</td>
<td>46.5</td>
<td>54.2</td>
</tr>
<tr>
<td>20% canola, 1.2 t/ha</td>
<td>mean $397 579</td>
<td>$401 053</td>
<td>$409 820</td>
<td>$405 683</td>
</tr>
<tr>
<td>CV (%)</td>
<td>38.7</td>
<td>38.7</td>
<td>38.7</td>
<td>41.1</td>
</tr>
<tr>
<td></td>
<td>Medium-High Rainfall Zone</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10% canola, 1.5 t/ha</td>
<td>mean $408 746</td>
<td>$415 615</td>
<td>$427 789</td>
<td>$416 588</td>
</tr>
<tr>
<td>CV (%)</td>
<td>38.9</td>
<td>38.6</td>
<td>38.3</td>
<td>42.6</td>
</tr>
<tr>
<td>20% canola, 1.5 t/ha</td>
<td>mean $412 451</td>
<td>$426 189</td>
<td>$450 537</td>
<td>$428 135</td>
</tr>
<tr>
<td>CV (%)</td>
<td>47.3</td>
<td>47.1</td>
<td>47.0</td>
<td>58.5</td>
</tr>
</tbody>
</table>

Table 2 Estimated environmental impact (EI) for four different canola production systems in Western Australia. Calculations are based on application rates of herbicides and the EI quotient (EIQ) for each. The estimated use is the proportion of paddocks under each system receiving each herbicide regime. These proportions were used to calculate the weighted average EI (Wt average EI) for each. The Average EI is the simple arithmetic average of the three values. ‘Roundup’ refers to Roundup Ready Herbicide in the RR system and Roundup PowerMAX in all others. The chief basis of comparison is triazine tolerant canola as it is the majority of canola currently grown in Western Australia.

<table>
<thead>
<tr>
<th>System</th>
<th>No.</th>
<th>Pre-emergent</th>
<th>Post-emergent</th>
<th>EI</th>
<th>Estimated use (%)</th>
<th>Average EI</th>
<th>Weighted average EI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Triazine tolerant</td>
<td>1</td>
<td>Atrazine, Simazine</td>
<td>Select</td>
<td>54.6</td>
<td>45</td>
<td>44.4</td>
<td>40.3</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Atrazine</td>
<td>Select</td>
<td>15.9</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Treflan, Atrazine</td>
<td>Simazine</td>
<td>62.8</td>
<td>15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roundup ready</td>
<td>1</td>
<td>Roundup</td>
<td>Roundup</td>
<td>9.5</td>
<td>32</td>
<td>19.9</td>
<td>16.4</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Roundup, Roundup</td>
<td>Roundup</td>
<td>19.0</td>
<td>63</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Treflan</td>
<td>Roundup, Roundup</td>
<td>28.1</td>
<td>5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clearfield</td>
<td>1</td>
<td>Roundup</td>
<td>Select, Intervix</td>
<td>12.1</td>
<td>30</td>
<td>14.2</td>
<td>14.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Treflan</td>
<td>Select, Intervix</td>
<td>10.2</td>
<td>30</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Treflan</td>
<td>Intervix, Roundup</td>
<td>20.4</td>
<td>40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conventional</td>
<td>1</td>
<td>Treflan</td>
<td>Select, Lontrel</td>
<td>10.2</td>
<td>45</td>
<td>11.9</td>
<td>10.8</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>Treflan</td>
<td>Verdict, Lontrel</td>
<td>10.5</td>
<td>45</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3</td>
<td>Treflan</td>
<td>Select, Dual Gold</td>
<td>15.1</td>
<td>10</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
was significantly less impacting than triazine tolerant canola. This comes about due to the use of relatively environmentally benign, foliar applied post-emergent herbicide in place of high residual, soil applied herbicide. In addition to the lower estimated environmental impact, Roundup Ready canola required slightly less fuel use and so produced slightly less carbon emissions compared with triazine tolerant canola (and in fact all other systems).

The trial data provided showed that Roundup Ready canola was on average 15 per cent higher yielding than triazine tolerant canola (data not shown). Although the agri-chemical and machinery costs for Roundup Ready canola were lower, the trait fee somewhat offset these savings. In the low rainfall areas, the combined impact of lower absolute yields, yield variability and the trait fee was sufficient to result in lower gross margins for Roundup Ready compared with triazine tolerant canola (although not significantly different). In other rainfall zones, yield differences needed to be at the upper end of the observed range in order to offset the trait fee and generate higher gross margins. The sensitivity of the profitability of Roundup Ready canola to this cost, particularly for the relatively low yields in the Western Australian farming system, needs to be stressed.

This analysis could be improved once local data, such as those from commercial trials carried out in WA in 2009, are available. A set of well-designed trials aimed to quantify the impacts of various canola systems in rotations, combined with economic and bio-physical modelling, would be better still. This would enable a broader analysis of the impacts of Roundup Ready canola, particularly on following cereal crops, in rotations in Western Australian farming systems.

If Roundup Ready canola is grown commercially in WA it is important that it is not used as a ‘silver bullet’ technology, but as another tool for farmers to make their systems more profitable and sustainable. The use of the technology needs to be couched in terms of clear conditions of use to ensure that it will still be a viable tool ten years from now and that potential negatives are minimised.

**KEY WORDS**
canola, herbicide use, environmental impact quotient, gross margin

**REFERENCES**

Farmanco 2008, Profit Series : benchmarking the top performers in agriculture. 104 pp. (Farmanco: Mundaring, WA).


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We would like to thank Cameron Weeks of Planfarm Geraldton for his advice on canola production systems in Western Australia and Dr James Neilsen of Monsanto Australia Ltd for providing raw data from the commercial canola trials conducted in New South Wales and Victoria.

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**Paper reviewed by:**
Robert Belford
Controlling wild radish (*Raphanus raphanistrum*) in Roundup Ready® Canola: Outcomes from the Nufarm 2009 Roundup Ready small plot trial program

Mike Jackson, Nufarm Australia Limited

**KEY MESSAGES**

The control of wild radish, a weed species prevalent throughout the wheat belt, is a key factor in growing successful crops of canola in Western Australia.

Under the conditions evaluated, 900 g/ha of Roundup Ready Herbicide applied twice, once at around 2-leaf with the follow up around 6-leaf, achieved exceptional control of wild radish.

A cautious approach in 2010 is still recommended whilst further evaluation on hydrophobic soil types is conducted. As Roundup Ready Herbicide offers no soil residual activity it is important to ensure solid crop stands. Therefore light sowing rates and strongly hydrophobic soils should be avoided.

**INTRODUCTION**

In December 2008 the Western Australian government issued an exemption order to the moratorium on the commercial cultivation of genetically modified crops in Western Australia. This exemption order that allowed limited cultivation of Roundup Ready canola and is ongoing was primarily designed to provide local experience as to whether the grains supply chain can effectively segregate GM from non-GM canola in Western Australia. A secondary aim was to examine the agronomic response of Roundup Ready canola under Western Australian conditions and challenges. This paper reports on a particular aspect to this secondary objective, namely the control of wild radish in the Roundup Ready canola system.

Wild radish is abundant throughout the Western Australian wheat belt, and this abundance alone has resulted in the dearth of conventional canola in the state, a situation unique to Western Australia. The vast majority of canola is triazine tolerant with the balance being Clearfield canola simply because of the need to control wild radish, a species that characteristically has a staggered germination placing additional demands on whichever herbicide system is used. Should the Roundup Ready canola system fail to provide satisfactory control of wild radish it would significantly limit its usefulness as a third herbicide option in Western Australia.

**AIM**

The project was designed to determine if wild radish can be effectively controlled in the Roundup Ready canola system, and to evaluate the impact of herbicide rate, single versus sequential herbicide applications, crop sowing rate, and the addition of Spraymate® Liase (Ammonium sulphate) on the level of control achieved.

**METHOD**

Trials were conducted on the properties of growers licensed to grow Roundup Ready canola crops in 2009. Two trials investigating the use of Liase with Roundup Ready Herbicide (RRH) were conducted in commercial Roundup Ready crops, and four trials investigating the impact of seeding rate on herbicide performance were seeded by Kalix Agriculture using six-row cone seeders. While the growers maintained the Liase trial sites in the normal operations of maintaining their commercial crops, Kalix Agriculture were responsible for maintenance of the seeding rate trials.

One seeding rate trial, based west of Wongan Hills, was discontinued without the trial being initiated when it was realised that inadequate opening rains had resulted in the crop largely dying below ground. A Liase trial, situated near Quairading did not have wild radish and is not part of this paper though excellent general weed control was achieved on other species. Three seeding rate trials, one north of Cunderdin, another near Bulyee and a third east of South Stirling, and one Liase trial south of Kamballup each had wild radish as a primary weed.
All seeding rate trials were seeded into dry soil. The Cunderdin and Bulyee trials were seeded on 14 May and 20 May respectively to the open pollinated variety, GT-61, supplied by Nuseed, while the South Stirling trial was seeded on 19 May to the hybrid, Hyola 601, supplied by Pacific Seeds. In each replicate half the plots were seeded at 2.8 kg/ha and the balance at 3.8 kg/ha. The seeding rate was randomised in the second and third replicates only. The Kamballup paddock was seeded at 2.5 kg/ha to 46-Y-20, a Pioneer Hi-Bred hybrid, in late May following rain. Each trial site received a knockdown herbicide (Roundup PowerMAX®1 or Spray.Seed®3) and a Trifluralin treatment where appropriate.

Test treatments (Roundup Ready Herbicide, 690 g/kg glyphosate as the mono ammonium salt) were applied at two stages of the crop. In the first spray window treatments were applied in a spray volume of 75 L/ha using AirMix®110–01 nozzles (nozzle output of 400 mL/min, ground speed 6.42 km/h) fitted to a five-nozzle (2.5 metre) hand held boom. Treatments in the second spray window were applied in a spray volume of 100 L/ha using AirMix110–02 nozzles (nozzle output of 600 mL/min, ground speed 7.2 km/h) fitted to a four-nozzle (2 metre) hand held boom. The switch to a smaller boom was made because it was noted that edge effects were too close to neighbouring plots. Trial plots were ten metres long and six-row or two metres wide on three metre centres. Each trial had three replicates, the first non-randomised.

Each trial examined Roundup Ready Herbicide at 600 g/ha, 900 g/ha, 1200 g/ha and 1500 g/ha applied at either the two-leaf crop stage only, the six-leaf crop stage only, or at both the two-leaf and six-leaf crop stages in a double treatment, the latter approach currently considered the preferred spray strategy.

In the seeding rate trials these treatments were duplicated on both seeding rates, while in the Liase trial the same treatments were applied with and without Liase at 2 per cent v/v in the spray mix.

RESULTS

In the Cunderdin trial a massive radish population was present across the entire site. The Bulyee trial also had wild radish throughout the trial but the population was uneven being dense only in the third replicate and parts of the second. The South Stirling trial had a modest population of wild radish essentially confined to the third replicate, while the Kamballup trial had a dense population throughout the first replicate but a light population through the second and third replicates. Consequently statistical analysis was confined to the Cunderdin and Bulyee sites by the final assessment.

Final assessments based on per cent visual control are provided in Table 1. These assessments were carried out eight and nine weeks after the 2-leaf application at the Cunderdin and Bulyee trial sites and twelve weeks after the 2-leaf application at the southern sites.

2-leaf application only: At all four sites Roundup Ready Herbicide applied at 900–1500 g/ha is believed to have achieved absolute control of wild radish when applied at the 2-leaf application window. The 600 g/ha treatment achieved a very high level of control but failed to kill all plants. The reduced levels of control of all 2-leaf only treatments shown in Table 1 capture the biomass impression of subsequent germination compared with the Untreated Check. The only apparent difference between the 600 g/ha treatment and the higher rate treatments being the presence of some obviously older, flowering wild radish plants the probably survived the herbicide application.

6-leaf application only: At all four sites Roundup Ready Herbicide treatments failed to achieve acceptable control of wild radish even at 1500 g/ha although there was a clear dose response evident. Whilst an unacceptable number of plants survived treatment the higher rates caused severe malformation of the wild radish inflorescence and most were incapable of producing viable pods.
Table 1  Per cent control of wild radish 8–12 weeks after the 2-leaf application of Roundup Ready Herbicide, and 4–8 weeks after the 6-leaf application

<table>
<thead>
<tr>
<th>Site</th>
<th>Cunderdin</th>
<th>Bulyee 9/5</th>
<th>Stirling 12/8</th>
<th>Kamballup 12/8</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weed popln at 2-lf crop stage</td>
<td>300/sqm</td>
<td>1–300/sqm</td>
<td>1–100/sqm</td>
<td>10–400/sqm</td>
</tr>
<tr>
<td>Weed age range (BBCH system)</td>
<td>10–12: 80%</td>
<td>10: 25%</td>
<td>10–12: 70%</td>
<td>10–13: 80%</td>
</tr>
<tr>
<td>Weed popln at 6-lf crop stage</td>
<td>1000/sqm</td>
<td>1–350/sqm</td>
<td>1–120/sqm</td>
<td>10–500/sqm</td>
</tr>
<tr>
<td>Weed age range (BBCH system)</td>
<td>10–14: 65%</td>
<td>12–15: 30%</td>
<td>10–14: 40%</td>
<td>10–14: 40%</td>
</tr>
<tr>
<td>Weed Popln at 6-lf crop stage, on plots treated at 2-lf stage</td>
<td>800/sqm</td>
<td>1–75/sqm</td>
<td>1–40/sqm</td>
<td>1–100/sqm</td>
</tr>
<tr>
<td>Weed age range (BBCH system)</td>
<td>10–13:100%</td>
<td>11–13:100%</td>
<td>10–13:100%</td>
<td>10–13: 100%</td>
</tr>
</tbody>
</table>

RRH @ 600 g/ha [2-lf only] 1 62 gh 77 ef 80 50
RRH @ 900 g/ha [2-lf only] 1 82 b 86 def 75 60
RRH @ 1200 g/ha [2-lf only] 1 73 cde 89 c-f 75 60
RRH @ 1500 g/ha [2-lf only] 1 80 bc 86 def 80 70
RRH @ 600 g/ha [6-lf only] 1 55 hi 67 f 70 30
RRH @ 900 g/ha [6-lf only] 1 63 fgh 78 ef 75 60
RRH @ 1200 g/ha [6-lf only] 1 72 def 69 f 90 80
RRH @ 1500 g/ha [6-lf only] 1 77 bcd 77 ef 95 85
RRH @ 600 g/ha [2-lf & 6-lf] 1 97 a 99 a-d 99 99
RRH @ 900 g/ha [2-lf & 6-lf] 1 99 a 100 ab 100 99
RRH @ 1200 g/ha [2-lf & 6-lf] 1 99 a 100 ab 100 100
RRH @ 1500 g/ha [2-lf & 6-lf] 1 100 a 100 a 100 100
RRH @ 600 g/ha [2-lf only] 2 65 * 89 c-f 85 80
RRH @ 900 g/ha [2-lf only] 2 80 * 87 def 98 70
RRH @ 1200 g/ha [2-lf only] 2 80 * 99 a-d 97 60
RRH @ 1500 g/ha [2-lf only] 2 78 * 96 a-d 98 70
RRH @ 600 g/ha [6-lf only] 2 50 i 71 ef 75 30
RRH @ 900 g/ha [6-lf only] 2 67 efg 77 ef 90 70
RRH @ 1200 g/ha [6-lf only] 2 75 b-e 91 b-e 95 80
RRH @ 1500 g/ha [6-lf only] 2 78 bcd 89 c-f 95 85
RRH @ 600 g/ha [2-lf & 6-lf] 2 97 a 99 abc 99 70
RRH @ 900 g/ha [2-lf & 6-lf] 2 99 a 99 abc 100 95
RRH @ 1200 g/ha [2-lf & 6-lf] 2 100 a 100 a 100 100
RRH @ 1500 g/ha [2-lf & 6-lf] 2 99 a 100 ab 100 100

CV 4.57 11.08
P(Bartlett's X2) 0.081 0.794
Treatment Prob(F) 0.0001 0.0001

Means followed by same letter do not significantly differ (P = .05, Duncan's New MRT).
Cunderdin data: Treatments (*) excluded from analysis prior to transformation to pass Bartlett's test for homogeneity.
Arcsine square root per cent transformation applied to Cunderdin and Bulyee data.
1 For Cunderdin, Bulyee and Stirling 1 denotes seeding rate of 2.8 kg/ha, for Stirling 2 denotes no Liase.
2 For Cunderdin, Bulyee and Stirling 1 denotes seeding rate of 3.8 kg/ha, for Stirling 2 denotes Liase at 2 % v/v.
Note: A number of treatments shown in this table as 100 per cent averaged between 99.5 and 99.9 per cent and rounded up.
2-leaf application followed by 6-leaf application: Absolute control was achieved by 900–1500 g/ha at all four sites. The less than 100 per cent scores in Table 1 reflect the presence of some very small wild radish plants that subsequently germinated. A very small number of plants may have survived the 600 g/ha double dose treatment based on the appearance of these plants.

DISCUSSION

Based upon these trials it is evident that a double spray strategy is vital to achieve satisfactory control of wild radish.

Adopting a single spray approach appears to be a poor strategy on a number of counts. If the treatment is applied too early it allows ample time for subsequent germination of wild radish as the crop is simply too young to provide effective competition. If the treatment is applied too late wild radish control will not only be incomplete but significant yield loss is likely to occur from prolonged weed competition.

A double spray strategy protects crop yield and achieves a very high level of control because in both spray windows the treatments target very young plants that are more vulnerable.

Figure 1 demonstrates the significant improvement of control achieved with the double spray strategy not only in terms of average control but also in terms of consistency.

The trials did not demonstrate any improvement in control achieved by increasing the seeding rate when using a double spray strategy (see Figure 2). Increasing the seeding rate does appear to suggest a minor improvement in control with single spray strategies, but control would probably still be unsatisfactory.

Data gathered from the Liase trial were unreliable given the uneven distribution of the wild radish population on this single site. Historically it is well documented that ammonium sulphate can enhance the performance of glyphosate, particularly under conditions of plant stress.

The Western Australia wheat belt notoriously has significant tracts of non-wetting country that would significantly impact on the performance of a herbicide system that provides no soil residual activity. While both the Cunderdin and Bulyee sites appeared to be marginally non-wetting, the 2009 trial program did not truly evaluate the Roundup Ready canola system in a significant non-wetting environment. An evenly germinating, solid canola crop is essential in achieving satisfactory weed control in the system, especially in the control of wild radish when there is no remedy beyond the 6-leaf stage of the crop. The intention is to investigate non-wetting soils thoroughly in future work.
CONCLUSIONS

Wild radish can be very effectively controlled in the Roundup Ready canola system using Roundup Ready Herbicide at 900 g/ha in a double spray strategy. A single spray strategy is unlikely to provide satisfactory control even at elevated rates.

Despite these findings, should the moratorium on the commercial cultivation of genetically modified crops in Western Australia be lifted or a new exemption order put in place it is recommended that caution be exercised in regard to paddock selection for Roundup Ready canola crops. It is advised that until the appropriate work has been conducted these crops should not be seeded into strongly non-wetting situations when the crop may not germinate effectively and wild radish is likely to germinate over an extended period.

KEY WORDS

Roundup Ready; canola; wild radish; sequential spray; GT-61; Hyola 601

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Weed control strategies for glyphosate tolerant crops

John Moore, Department of Agriculture and Food, Western Australia, Albany

KEY MESSAGES

At least two varieties of Roundup Ready canola will tolerate high rates of isopropyl amine or potassium salt formulations of glyphosate at the 1 to 4 leaf stage but these will require registration before field use.

Annual Ryegrass control with glyphosate at label rates is marginal when applied within 15 days of the break of the season due to staggered emergence of the ryegrass and poor efficacy on very young seedlings.

Glyphosate in combination with metolachlor (Dual® Gold) provided good control of Annual Ryegrass when applied 10 days after the break. This provides a potentially new technique for weed control in Roundup Ready crops as metolachlor doesn’t require mechanical incorporation but it does require registration for post-emergence applications before field use.

BACKGROUND AND AIMS

The introduction of glyphosate tolerant crops will require a range of new agronomic practices to ensure maximum short term and long term profits from the new technology. Practices to reduce the build up of glyphosate resistance are required. Recent work (Gaines et al. 2009) has indicated that while glyphosate resistance appears to be based on a single gene, multiple copies or gene amplification could result in increasing tolerance with multiple applications of low rates in Amaranthus. If this same phenomenon occurs in Annual Ryegrass and/or Wild Radish then higher levels of control may be warranted to delay resistance. This could be achieved by higher rates of glyphosate, later timings of application, multiple applications, use of other herbicides and the incorporation of other practices that provide weed suppression.

Staggered germination of both Annual Ryegrass and Wild Radish have been a problem in glyphosate tolerant canola. This has been compounded by the requirement to apply post-emergence glyphosate before the 6-eaf stage in the current set of canola varieties.

The two trials reported here investigated the dose response of alternative formulations of glyphosate in glyphosate tolerant canola and the use of pre-emergence herbicides in combination with glyphosate to achieve higher levels of Annual Ryegrass control. These results and other observations have been used to suggest potentially new practices and the research required to have them approved and adopted.

Trial 1

METHOD

An isopropyl amine (Roundup Biactive®) and a potassium salt (Roundup PowerMAX®) formulation of glyphosate were applied at rates ranging from 500 to 5000 g.a.i./ha on two varieties (502 and 601) of Roundup Ready canola at the 1 to 4 leaf stage (15 July). This was compared to the normal application of 900 g/ha Roundup Ready Herbicide (mono ammonium salt) applied on 14 July and repeated on 4 August in the bulk crop and over the trial area. The canola was planted on 15 June with 1450 mL/ha Triflur Xcel, 80 kg/ha Cropstar fertilizer and had 60 kg urea on 24 July and 14 August.

RESULTS

Both varieties of Roundup Ready canola tolerated high rates of the two formulations tested (Figure 1).

The yields of the surrounding bulk crop were 1.7 t/ha for 502 and 2.1 t/ha for 601 variety. The slightly higher yields in the trial area are probably due to paddock variation and reduced losses due to hand harvesting of the trial plots. Weed control was excellent in the plot and bulk areas.
Trial 2

METHOD

Approximately 100 kg/ha of Annual Ryegrass seed was lightly cultivated into an infested paddock at the break of the season to produce a high density Annual Ryegrass infestation.

Glyphosate (Roundup PowerMAX®) at 125 to 2500 mL/ha was applied with a logarithmic sprayer at four times (10, 15, 23 and 42 days after planting Annual Ryegrass). At the first time of spraying Dual Gold (metolachlor) was applied at 200 to 4000 mL/ha by itself and in a mixture with PowerMAX with rates ranging from 125 mL PowerMAX plus 200 mL/ha Dual Gold to 2500 mL/ha PowerMAX plus 4000 mL/ha Dual Gold.

RESULTS

The control of Annual Ryegrass at normal rates of glyphosate applied 10–15 days after planting was poor. This was due to both poor efficacy on very young ryegrass and staggered germination of the seed. By 23 days after planting, control with glyphosate was acceptable and by 42 days after planting control with low rates of glyphosate was excellent (Figure 2).
Figure 2 The apparent control of Annual Ryegrass sprayed with various rates of Roundup PowerMAX (glyphosate 540g/L) 10, 15, 23 and 42 days after planting Annual Ryegrass.

Glyphosate reduced Annual Ryegrass density by less than 50 per cent when applied 10 days after planting regardless of the rate. Metolachlor provided good control at rates above 2 L/ha but some plants that emerged before spraying escaped control. Better control was achieved with the mixture at rates greater than 625 mL/ha of Roundup PowerMAX with 1 L/ha Dual Gold (Figure 3).

Figure 3 Annual Ryegrass density after application of various rates of glyphosate (Roundup PowerMAX), metolachlor (Dual Gold) and a mixture of glyphosate and metolachlor. (Doses on the x axis are the rates of glyphosate or metolachlor in the single and mixture treatment).
CONCLUSION

There is scope to use high rates and alternative formulations of glyphosate in Roundup Ready canola varieties. These will require registration before farmers may use them and may require more trial work. The tolerance to glyphosate demonstrated here suggests that multiple applications or applications at other growth stages using lower rates may be possible and should be investigated. New varieties are also expected to be more tolerant to late applications. The need for later application timings has been confirmed this year where Annual Ryegrass and Wild Radish emerged after the last application of glyphosate resulting in weed seed production at some sites in the GM trial program. Selective crop topping is another technique that relies on late applications of herbicide and has been effectively used to run down Wild oat seed banks (Medd et al. 1992). This technology could be transferred to Annual Ryegrass using glyphosate providing sufficient tolerance is demonstrated.

The ability of Annual Ryegrass to flourish after glyphosate applications within three weeks of the break of the season dictates that pre-emergence herbicides or late post-emergence weed control will be required for adequate control. Glyphosate tolerant crops allow the application of glyphosate later in the season when Annual Ryegrass is susceptible the low rates shown in Figure 2. Alternatively, mixtures with pre-emergence herbicides such as metolachlor that don’t require mechanical incorporation allow the use of glyphosate to control a range of weeds without compromising Annual Ryegrass control as shown in Figure 2. In old trials using old varieties, canola has tolerated post-emergence applications of metolachlor (Moore, 2000), so the mixture has potential for use in Roundup Ready canola. Again this requires further trial work to obtain registration and measurements of the levels of residues in the crop for this novel timing of application.

In broadacre production systems, there is often a compromise between the time of sowing, waiting for weeds to emerge, early weed control to reduce competitive effects, late weed control to reduce grain contamination and weed seed banks and optimising herbicide use to reduce the risk of resistance. Glyphosate tolerant crops allow the application of glyphosate after the bulk of the Annual Ryegrass has emerged and reached a size where it is susceptible to low rates of glyphosate (or very high levels of control at label rates). Application of glyphosate up to three weeks after planting will require a follow up sprays or mixtures with pre-emergence herbicides. In dense infestations of Annual Ryegrass this delay may result in a grain yield loss due to early competition. One could envisage early spraying with herbicide mixtures in heavily infested, early planted paddocks and delayed spraying in lightly infested or late planted paddocks. Very late applications of glyphosate allow better manipulation of seed set control for following crops and running down Annual Ryegrass seed banks. For intractable weeds such as Wild Radish in canola, the use of alternative herbicides is limited because of the close affinity between the weed and crop. Herbicide tolerant crops will be an essential tool to achieve the required selectivity for effective herbicidal weed control. New varieties with greater tolerance to late applications and research to confirm efficacy, tolerance and residue levels will be required to obtain registration.

Glyphosate tolerant crops will allow the producer more flexibility in their weed control and logistical operations. Strategies involving the use of alternative formulations (which is driven mainly by price), higher rates or multiple applications (which is driven mainly by the lack of alternative control measures) and mixtures with residual herbicides or later timings of application (which is driven mainly by the weed germination pattern and crop tolerance) are all potentially useful but require further validation and registration. Overlaying this is the risk of resistance which could be significantly influenced if Annual Ryegrass or Wild Radish is able to implement the gene amplification demonstrated in Amaranthus last year in the USA.

KEY WORDS

Annual Ryegrass, glyphosate, GM Canola, Lolium rigidum, metolachlor, resistance, logarithmic sprayer, Roundup, Roundup Ready Canola

ACKNOWLEDGMENTS

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Paper reviewed by: Dr Sally Peltzer
Results of the 2009 Western Australia Roundup Ready® canola trials

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KEY MESSAGES

The commercial trial of Roundup Ready® canola demonstrated the agronomic suitability of the Roundup Ready system for the Western Australian cropping region. The level of weed control achieved at the 17 commercial sites was rated as excellent by 90 per cent of growers and the yield of the Roundup Ready system was higher than the herbicide tolerant canola systems at 75 per cent of the sites. Independent results from the herbicide tolerant canola national variety trial sites established in Western Australia showed that on average Roundup Ready canola had a 15 per cent yield increase over triazine tolerant canola.

AIMS

A commercial trial of Roundup Ready canola was undertaken in Western Australia in 2009, with 17 commercial growers and three research and development sites growing around 850 ha. The trial was established to evaluate the agronomic performance of Roundup Ready canola and to address the issue of supply chain segregation. This paper reports the weed control and yield results from the trial, as well as yield results from the national variety trial sites in Victoria, New South Wales and Western Australia.

RESULTS

Weed Control and Herbicide resistance

The weed control achieved by the Roundup Ready system was rated as excellent by 90 per cent of Western Australian trial growers in 2009 (Figure 1). Three quarters of the trial growers implemented a two spray strategy applying Roundup Ready herbicide twice with the first application at around the two leaf stage of the canola with the second prior to the sixth true leaf. In some situations two applications of Roundup Ready herbicide were not possible due to spraying conditions and high early vigour taking plants outside the application window. Growers of the system need to be aware of crop development within the window and monitor it closely and also monitor any subsequent weed germinations and plan to have early canopy closure to provide crop competition. Lack of early canopy closure contributed to some poor weed control on the East coast (Figure 1) in addition to environmental conditions, shading of weeds and late weed germinations.

![Figure 1 2009 Roundup Ready herbicide weed control](image)

Western Australian growers have commented that the most important benefits of Roundup Ready canola as the increased weed control flexibility it provides, as well as the rotational benefits and in particular the ability to reduce and rotate the use of Group A and B herbicides. John Snooke one of the 17 commercial growers of Roundup Ready canola in 2009 said ‘The crop rotation benefits are of most
value to me, allowing me to decrease the pressure on my Group A and B cereal herbicide options. I will include Roundup Ready canola as 30–50 per cent of my canola program going forward to reduce my reliance on grass selective herbicides so they are more effective when I need them.

As part of the Resistance Management Plan for Roundup Ready canola growers need to complete the Paddock Risk Assessment and Management Option Guide (PRAMOG®) a risk assessment process on a paddock by paddock basis. The three steps in completing 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 depends on the type of application (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. This herbicide resistance status of a paddock reflects the outcomes of previous management practices and is an indicator of the resistance pressure that has already been placed on glyphosate.

The resulting risk profile mandates growers implement either one (Category 1) or two (Category 2) non-glyphosate based management practices in the year following Roundup Ready canola and if the risk is high (Category NG) it is recommended in addition that farmers do not use glyphosate in the year following Roundup Ready canola.

The PRAMOG category results were different between the East and West coast growers in 2009. A much higher proportion of Western Australian growers were in the NG category when compared to the East Coast (Figure 2). This is driven primarily by a historically more intensive use of glyphosate in Western Australia and also by pre-existing level of herbicide resistance to multiple herbicide modes of action. Almost 90 per cent of the 20 (including the 3 R&D sites) 2009 Western Australian growers had resistance to at least one herbicide mode of action, compared to approximately 70 per cent for the Eastern states.

![Figure 2. 2009 Roundup Ready canola PRAMOG paddock classification](image)

**Yield**

The yield results for all 17 commercial growers Roundup Ready canola including results from corresponding fields of triazine tolerant and Clearfield canola where grower results are available are presented in Figure 3*. Roundup Ready canola yield varied from 0.6 to 2 t/ha and was higher than the comparable systems in 75 per cent of comparisons (n = 12).
Figure 3 Comparative yield of Roundup Ready (n = 17), Triazine tolerant (n = 12) and Clearfield (n =3) canola grown by the 17 commercial trial growers in Western Australia in 2009. Multiple points for the same grower number indicate where data from more than one canola system is available for comparison.

In addition to the commercial yield results, the GRDC conducted 15 herbicide tolerant canola National Variety Trials (NVT) in Australia in 2009, five in each of New South Wales, Victoria and Western Australia. The results from 11 of these sites have been released.

For a systems analysis of this data the most statistically valid comparison utilizes the maximum number of data points available. In this case this was governed by the number of varieties included in each system in the trials. As there were only six Clearfield varieties in the trials, the top six varieties from each herbicide tolerant system were selected for comparison to eliminate statistical bias.

The average yield of the six highest yielding varieties from each herbicide system is presented in Table 1. The NVT results showed that the Roundup Ready varieties yielded 2.08 t/ha across the 11 sites compared to the Clearfield® system at 1.97 t/ha and the triazine tolerant system at 1.87 t/ha. This 11 per cent yield increase from Roundup Ready over the triazine tolerant is consistent with grower experience from the 2008 and 2009 seasons.

In Western Australia Roundup Ready canola had the same average yield as Clearfield and both were 15 per cent higher than the average than triazine tolerant.

* System comparison results were only available for 12 growers at the time of publication.

Table 1 Summary of 2009 herbicide tolerant canola NVT results for New South Wales, Victoria and Western Australia
CONCLUSION

The results of the trial show that the Roundup Ready canola production system suits the cropping regions of Western Australian. Although on average the Western Australian glyphosate resistance risk was higher than in the Eastern States, the resistance management plan for Roundup Ready canola takes this level of risk into account and helps growers protect the sustainable use of glyphosate in a farming system that includes Roundup Ready canola.

Roundup Ready canola has enabled the Western Australian commercial trial growers to achieve excellent weed control without sacrificing yield.

KEY WORDS

glyphosate, Genetic Modification (GM), herbicide resistance

ACKNOWLEDGMENTS

Monsanto would like to acknowledge the 17 commercial growers who grew Roundup Ready canola in Western Australia in 2009 as part of the commercial trial.