Performance of Canola Breeders Roundup Ready® canola hybrid CHYB-166 in 2008

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KEY MESSAGES

Canola Breeders are developing RR® canola hybrids in conjunction with partner company NPZ in Germany and Canada. Test hybrids were produced in Chile summer 2007–08, and imported into eastern Australia after the lifting of the moratoria on genetically modified canola in NSW and VIC in early 2008. Trials were conducted in NSW and VIC in 2008 to test yield, blackleg resistance and quality of Canola Breeder's RR® hybrids against conventional hybrid Hyola® 50 and open-pollinated conventional and triazine tolerant canola lines. The most promising RR® hybrid CHYB-166 out-yielded open-pollinated conventional lines by 10% and triazine tolerant lines by 20%, and was equivalent in yield to Hyola® 50. Oil content and blackleg resistance of CHYB-166 was equal to the best open-pollinated lines. These trials demonstrated the benefits of hybrid vigour in canola and showed that Canola Breeders RR® hybrids will provide major economic benefits to growers.

AIMS

The goal of this work was to test the yield potential of new RR® canola hybrids developed by Canola Breeders at two locations in eastern Australia in 2008. In particular, we were interested in the performance of an early-mid season maturity RR® hybrid, CHYB-166.

METHOD

Test RR® hybrids were formed in collaboration with NPZ using the MSL hybrid system. Seed of test hybrids was imported into eastern Australia after the lifting of the moratoria on genetically modified RR® canola in April 2008. Two replicated field trials were conducted near Lake Bolac, Victoria, and Walla Walla, NSW, during 2008. The trials contained conventional and triazine tolerant (TT) open-pollinated (OP) varieties, and a conventional hybrid Hyola® 50, in addition to test RR® hybrids from Canola Breeders. Harvested plot area was 10 m x 1.6 m. Grain samples from each plot were tested for quality traits (oil, protein, glucosinolates) by near-infrared radiation. Yield and quality data were analysed by multi-environment trial analysis using ASReml, and included trial spatial adjustments. In order to compare across herbicide tolerance groups within the trials, glyphosate and triazine herbicides were not applied to the trials.

RESULTS

There was significant impact from drought at both locations, and yield was lower than the long term average for these sites. Nevertheless, yield of CHYB-166 was equivalent to Hyola® 50, and consistently 10% higher in yield than conventional OP varieties and 20% higher than TT varieties (Table 1).

The oil, protein and glucosinolates of CHYB-166 were average among the range of varieties listed in Table 2, and blackleg resistance was equivalent to MR-MS types (such as ATR-Barra) in the national blackleg rating scheme (Table 2).

Table 1 **Yield (t/ha) of RR® hybrid CHYB-166 and other varieties at two sites in VIC (Lake Bolac) and NSW (Walla Walla) in 2008 (SE = standard error)**

ID	Variety type	NSW	SE	VIC	SE	Average	SE	Ranking	% CHYB-166
CHYB-166	Hyb RR	1.34	0.06	1.27	0.05	**1.30**	**0.05**	1	100
HYOLA_50	Hyb Conv	1.31	0.09	1.25	0.09	**1.28**	**0.09**	2	98
AG-MUSTER	Op Conv	1.22	0.07	1.15	0.07	**1.18**	**0.07**	3	91
AG-COMET	Op Conv	1.14	0.07	1.06	0.07	**1.10**	**0.07**	4	84
AV-SAPPHIRE	Op Conv	1.14	0.09	1.06	0.09	**1.10**	**0.09**	5	84
ATR-BARRA	OP TT	1.13	0.09	1.05	0.09	**1.09**	**0.09**	6	83
RIVETTE	OP Conv	1.09	0.09	1.00	0.09	**1.04**	**0.09**	7	80
CB TANAMI	OP TT	1.03	0.07	0.94	0.07	**0.98**	**0.07**	8	75
AV-JADE	OP Conv	1.01	0.09	0.92	0.09	**0.96**	**0.09**	9	74
AG-CASTLE	OP Conv	0.97	0.07	0.88	0.07	**0.92**	**0.07**	10	71
CB TRIBUNE	OP TT	0.95	0.07	0.86	0.07	**0.90**	**0.07**	11	69
CB BOOMER	OP TT	0.95	0.07	0.86	0.06	**0.90**	**0.07**	12	69
CB TELFER	OP TT	0.87	0.07	0.77	0.07	**0.82**	**0.07**	13	63

Table 2 **Grain quality and blackleg resistance of Canola Breeders RR® hybrid CHYB-166 and other varieties at two sites in VIC and NSW in 2008**

ID	Variety type	Oil %[1]	Protein seed %[1]	GSL[2]	Blackleg[3]
CHYB-166	Hyb RR	42.5	24.6	13.6	7.7
HYOLA_50	Hyb Conv	44.1	24.4	14.8	4.2
AG-MUSTER	Op Conv	41.9	24.3	16.9	24.5
AG-COMET	Op Conv	41.9	23.5	22.0	14.9
AV-SAPPHIRE	Op Conv	44.5	24.0	19.2	16.7
ATR-BARRA	OP TT	42.2	26.0	13.4	7.6
RIVETTE	OP Conv	43.4	25.4	17.6	23.9
CB TANAMI	OP TT	39.8	25.6	22.0	26.3
AV-JADE	OP Conv	44.0	25.9	15.6	11.6
AG-CASTLE	OP Conv	45.1	23.9	15.0	12.9
CB TRIBUNE	OP TT	40.7	24.8	12.9	3.7
CB BOOMER	OP TT	41.1	25.9	14.7	28.3
CB TELFER	OP TT	42.1	24.7	12.0	17.5

[1] Oil and protein are expressed as a percentage of dry seed weight.
[2] Glucosinolates (GSL) are expressed in units of micromoles per gram.
[3] Blackleg rating is the mean number of mature plants lodged per plot due to blackleg disease.

CONCLUSION

CHYB-166 is one of a new generation of RR® hybrids that will help to lift the average yield of canola across southern Australia. This work confirms that canola hybrids provide valuable improvements in canola yield, and this value is now available in an RR® background. Canola Breeders will provide greater choice to growers through the future release of canola RR® hybrids such as CHYB-166.

KEY WORDS

Canola, Roundup Ready®, hybrids

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The implications of GM glyphosate resistant lupin

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KEY MESSAGES

The total on-farm benefit of introducing GM glyphosate resistant lupin into Western Australia would be nearly $40 million per year. This figure is after tax and is in addition to the economic returns estimated for GM glyphosate resistant canola but does not account for any fee for access to the GM technology. The size of the technology fee is unknown but such a fee would reduce the benefit to farmers.

Introducing GM glyphosate resistant lupin into WA will accelerate the build-up of glyphosate resistant weeds, making it imperative to introduce the new technology along with a stewardship package to prolong the useful lifetime of glyphosate. The stewardship package would not provide least-cost weed management in the short term. Rather, it would provide growers with a durable weed management strategy, very low weed numbers and insurance against blow-outs if individual weed management activities fail for any reason.

The stewardship package must be developed in consultation with growers to ensure that it is cost-effective and practical.

AIMS

To examine the potential place of GM glyphosate resistant lupin in Western Australian farming systems, including effects on returns to farmers and effects on glyphosate resistance in weeds.

METHOD

This work was done in consultation with focus groups made up of farmers and agriculture consultants.

Development of glyphosate resistance in weeds

Development of glyphosate resistance in annual ryegrass (considered to be the weed most at risk of developing glyphosate resistance in WA) was estimated using a computer model. The estimate was done for the medium rainfall cropping region of the northern agricultural district of WA. The modelling took account of crop rotations, gene mutation rate, equilibrium gene frequency of resistance genes, history of glyphosate use up to present, crop seeding rates, ryegrass survival rates under herbicide regimes in crop and pasture, competition between normal and resistant plants, and competition between species.

The model considered nine different management options to determine the amount of time until glyphosate resistance would become common in ryegrass (Table 1). These options were combinations and variations on four basic strategies: 1) reducing the use of glyphosate as a pre-plant non selective herbicide; 2) using GM glyphosate resistant crops less frequently; 3) killing or removing ryegrass seed at harvest (e.g. windrow burning); 4) using other herbicides in combination with glyphosate in the GM crop (e.g. the double knock or alternate selective herbicides).

Table 1 **Management options evaluated**

Management option	Description
1. No GM crops	An eight year cycle with two years of lupin, one of canola and one of pasture, wheat/lupin/wheat/lupin/wheat/canola/wheat/pasture, with pre-plant glyphosate in all crop years.
2. Standard GM strategy (SGM)	A seven year rotation cycle with three GM crops, wheat/GM glyphosate resistant lupin/wheat/GM glyphosate resistant canola/wheat/GM glyphosate resistant lupin/wheat, with pre-plant glyphosate in wheat years only.
3. SGM with pre-plant glyphosate all years	Pre-plant glyphosate in the GM glyphosate resistant lupin and canola years as well as in the wheat years.
4. SGM with no pre-plant glyphosate	No pre-plant glyphosate, an alternate pre-plant herbicide used in all years.
5. SGM with 1 year of conventional lupin in 7	One of the two GM glyphosate resistant lupin crops replaced by conventional lupin in each 7 year rotation.
6. SGM + windrows burnt in canola and lupin	Windrows burnt to kill ryegrass seed in the GM glyphosate resistant lupin and canola crops, but not the wheat.
7. SGM + additional herbicide in lupin	An additional herbicide was applied to GM glyphosate resistant lupin, controlling 90% of surviving ryegrass. This strategy is similar but probably more effective than a double knock.
8. Comprehensive husbandry	The SGM strategy with no pre-plant glyphosate for any crop, windrows burnt in canola and lupin, and additional herbicide used in lupin.
9. Intensive GM strategy (overuse of glyphosate)	A wheat/GM glyphosate resistant lupin/wheat/GM glyphosate resistant canola rotation, with more intensive use of glyphosate in the lupin and canola years and a reduced level of control by alternate selective herbicides in the wheat years.

An important unknown factor in forecasting development of resistance is the fitness penalty due to resistance, which is the amount of reduction in seed produced by resistant ryegrass plants in the field as a proportion of the amount produced by susceptible plants. A range of fitness levels were tested. They were chosen to be consistent with the rate of development of glyphosate resistance in ryegrass in winter fallow systems on the Liverpool plains of NSW, and systems in Alberta Canada where Roundup Ready® canola has been used since its development in the mid 1990s and no glyphosate resistance has yet developed even in resistance prone weeds such as wild oats. Fitness penalties of 20%, 33% and 50% were considered possible. It is unlikely that there would be no fitness penalty, but a 1% penalty was included for comparison.

Economic benefits

The STEP (Simulated Transitional Economic Planning) model was used to estimate the economic returns that could be expected over a 20-year period from introducing GM herbicide resistant lupin in Western Australia in the regions shown in Figure 1. The economic benefit provided by GM glyphosate resistant lupin over and above the benefit of GM glyphosate resistant canola was estimated for all regions. For each region the area of soil suitable for GM lupin was estimated. For the area of suitable soil, the annual surplus of the most profitable rotation that included both GM glyphosate resistant lupin and GM glyphosate resistant canola was compared to the most profitable rotation using GM glyphosate resistant canola alone. The rotations used for each region are shown in Table 2. For the changes in yields, costs, and terms of trade, but not including interest on loans. The calculations did Mingenew region a number of additional management strategies were also examined. These analyses account for all costs and returns including fertiliser, sprays, fuel, repairs, crop insurance, taxation, and not include a fee for use of the GM glyphosate resistant technology, as the size of such a fee for GM glyphosate resistant lupins is unknown.

Table 2 **Representative rotations for employing GM lupin and canola or GM canola only**

Region	Rotation, GM canola only	Rotation, GM lupin and GM canola
Mingenew region (Northern)	wheat/lupin/wheat/lupin/wheat/ GM canola/wheat/pasture	wheat/GM lupin/wheat/GM canola/ wheat/GM lupin/wheat
Mullewa region (Northern dry)	fallow/wheat/wheat	GM lupin/wheat/wheat/fallow/wheat/ wheat
Quairading region (Central)	wheat/barley/pasture/wheat/wheat/ GM canola	wheat/barley/GM lupin/wheat/wheat/ GM canola
Burracoppin region (Eastern dry)	wheat/barley/pasture/wheat/wheat/ GM canola	wheat/barley/GM lupin/wheat/wheat/ GM canola
Pingaring region (South Central)	wheat/barley/GM canola	wheat/barley/GM lupin/wheat/barley/ GM canola

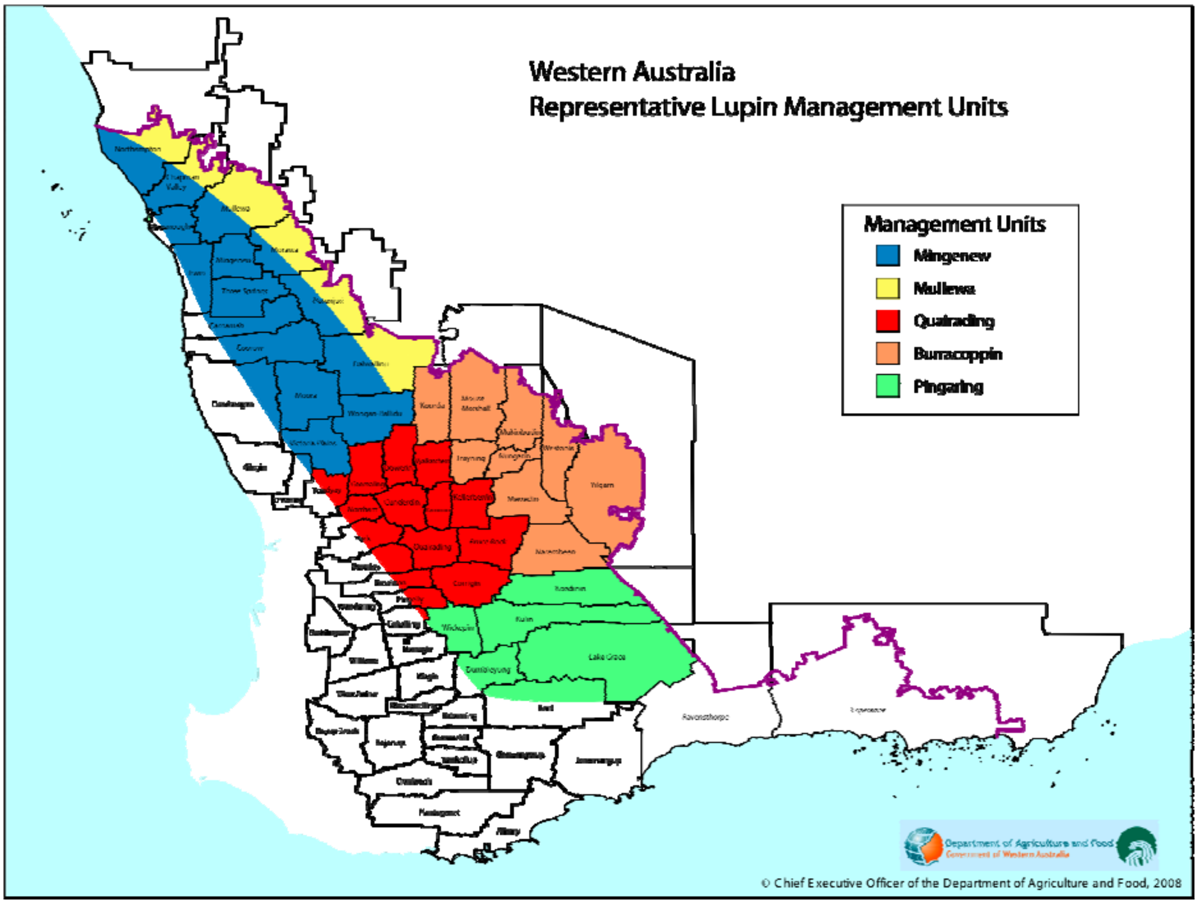

Figure 1 Representative regions of the Western Australian wheatbelt used for the economic analysis of GM lupin.

RESULTS

Development of glyphosate resistance in weeds

The number of years until herbicide resistance becomes widespread in annual ryegrass for each of the possible levels of fitness penalty due to glyphosate resistance is shown in Table 3.

Table 3 **Years until glyphosate resistance becomes common**

Management applied	Fitness penalty from resistance*			
	Realistic (33%)	Pessimistic (20%)	Optimistic (50%)	No penalty (1%)
1. No GM crops	> 32	23	> 32	8
2. Standard GM strategy (SGM)	14	11	21	5
3. SGM with pre-plant glyphosate all years	12	9	17	5
4. SGM with no pre-plant glyphosate	21	14	> 32	7
5. SGM with 1 year of conventional lupin in 7	18	12	28	5
6. SGM + windrows burnt in canola and lupin	22	15	> 32	5
7. SGM + additional herbicide in lupin	29	19	> 32	6
8. Comprehensive husbandry	> 32	> 32	> 32	> 32
9. Intensive GM strategy	9	7	13	4

* The reduction in seed produced on resistant plants relative to susceptible plants.

Economic benefits

Economic benefits of employing both GM glyphosate resistant lupin and canola together with several possible husbandry strategies are shown for the Mingenew (Northern) region in Table 4. These figures do not include a fee for access to the GM technology.

Table 4 **Results, estimated over 20 years for various management strategies for the Mingenew region**

Management strategy	Average annual surplus ($/ha/year)	Benefit above current system ($/ha/year)	Benefit to the region above current system ($million/year)
No GM crops (100% crop assuming crop yields will decline)	76	-9	-6.9
No GM crops (includes a pasture phase)	85	0	0
No GM crops (100% crop assuming maintenance of yields)	94	9	6.9
Standard GM strategy (SGM)**	122	37	28.4
SGM but with 1 year of conventional lupin in 7	118	34	26.1
SGM + windrows burnt in canola and lupin	126	42	32.3
SGM + additional herbicide in lupin	119	35	26.9
SGM with GM canola only (conventional lupin replacing both GM lupin crops)	116	31	23.8
SGM with GM canola only, plus a 1 year pasture phase	105	20	15.3

The on farm value of employing GM glyphosate resistant lupin and canola together is compared with the value of employing only GM glyphosate resistant canola in Table 4 for all of the regions, giving the value of GM glyphosate resistant lupin to WA farm income after tax but not including a fee for access to the GM technology. The impact of a technology fee on the economic benefits gained from using GM glyphosate resistant crops under a standard GM strategy is shown in Table 6.

Table 5 **Estimated value of GM lupin over and above GM canola for all regions and for all of WA**

Region	Average annual surplus ($/ha/year)			Additional value of GM lupin to the region ($ million/year)
	GM canola rotation	GM lupin and GM canola rotation	Additional value of GM lupin	
Mingenew (Northern)	105	122	17	13.1
Mullewa (Northern dry)	28	40	12	4.8
Quairading (Central)	85	97	12	8.0
Burracoppin (Central dry)	59	73	14	12.7
Pingaring (South Central)	253	161	Nil	Nil
			WA total	**38.6**

Table 6 **Impact of a technology fee on the economic benefits gained from using GM crops under a standard GM strategy**

Technology fee ($/mt of GM crop)	Cumulative cost to WA ($ million/year)
5	5.1
10	10.3
15	15.4

CONCLUSION

The model does not predict a suitable outcome if glyphosate resistant lupins are simply introduced into the cropping system. The time to development of glyphosate resistance would be reduced from 20 to 30 years without GM's to 10 to 15 years with the standard GM rotation. This result could be made substantially worse by continuing to use glyphosate as a pre-plant herbicide in all years, or by intensifying the use of GM crops.

A number of strategies would be effective in increasing the time until glyphosate resistance develops in ryegrass. Completely cutting out the use of pre-plant glyphosate, or killing ryegrass seed by burning windrows in lupin and canola both delay the development of resistance by 5 years or more. Burning windrows, or killing or removing seed by other means in all years if it could be achieved, would be more effective still. Using an additional herbicide with 90% efficacy against surviving ryegrass in GM glyphosate resistant lupin would be quite effective, delaying development of resistance almost to the same degree as not using the GM crops. The additional herbicide could be one for which any existing lupin has a natural tolerance, or it could be added by mutagenesis or GM methods. Combining these tactics makes them more effective. The strategies that use extra control measures, like seed killing and additional herbicides, depend on driving ryegrass numbers to very low levels before resistance develops, so they will only work if all other control tactics in the rotation are maintained even when ryegrass becomes scarce.

Employing GM crops in the medium rainfall northern region of WA would have a substantial economic benefit estimated at $37/ha/year not including a fee for the GM technology. Burning windrows in the lupin and canola years is the most cost-effective husbandry strategy tested, raising the benefit by $5/ha/year. Employing an additional herbicide in the GM glyphosate resistant lupin would not increase the estimated benefit. The advantage from delaying resistance occurs late in the 20 year accounting period and because of discounting it is offset by the cost of the extra herbicide in the early years, however, the benefit from this strategy would continue beyond 20 years.

The total benefit to WA farm income from introducing GM glyphosate resistant lupin over and above the benefit from GM glyphosate resistant canola is estimated to be 38.6 million dollars per annum. This value is approximate and reflects the particular set of assumptions used. It is probably better to think of this estimate as being in the order of 40 million dollars per annum. Any fee for use of the GM technology would reduce this amount. In the Mingenew (Northern), Quairading (Central) and Burracoppin (Eastern dry) regions, the increased income comes from replacing pasture with GM glyphosate resistant lupin. In the Mullewa (Northern dry) region the benefit is from replacing fallow with GM glyphosate resistant lupin in years with a favourable break to the season. In the Pingaring (South Central) region, where canola is relatively well adapted, no rotation that included GM glyphosate resistant lupin was found to be more profitable than rotations with only GM glyphosate resistant canola. We anticipate that this situation would be similar in the remainder of Western Australia

KEY WORDS

genetically modified, Roundup Ready®, *Lolium rigidum*

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