Integrated Weed Management can Decimate Wild Radish in Three Years

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Key messages

- Three years (2014 to 2016) of integrated weed management (IWM) to control wild radish has shown that effective knockdowns (single or double knock), non-chemical weed control options and application of effective in-crop herbicide mixtures can significantly reduce the wild radish population.
- Effective post-emergent (PO) mixtures of herbicides provide a greater gross margin than use of a higher seed rate, although non-chemical weed control options are of significant importance to delay the evolution of resistance by wild radish.
- High seed rate reduced radish density in one out of three years but did not affect grain yield in any year at this site. The overall grain yield of wheat was low, probably due to the high level of soil compaction at 100-300 mm depth.

Aims

A trial was established at Dalwallinu, WA in collaboration with Liebe Group, to raise awareness of IWM techniques on wild radish control. The trial (2014-2016) demonstrated the effect of chemical and non-chemical options to improve the control of wild radish over time, and to minimise the development of herbicide resistance in wild radish.

Method

Selective control options available at pre-sowing, post-emergence (PO), and at harvest time were incorporated into IWM options. In-crop herbicides included Triathlon® (mixture of Group C+F+I) and Velocity® (mixture of Group C+H). These were used along with two seed rates, windrow burning (WRB) and harvest weed seed removal (HWSR) as wild radish control options. The wild radish population at this site was resistant to chlorsulfuron. All treatments from 2014 to 2016 are provided in Table 1.

Trial Details 2014 to 2016

Property location	Michael Sawyer's property, Nugadong East Road, Dalwallinu
Plot size & replication	10m x 3m x 4 replications in 2016; 20m x 3m x 4 replications in 2014 and 2015
Soil type	Sandy loam
Soil pH ($CaCl_2$)	0-10cm: pH 5.3
EC (dS/m)	0-10cm: 0.15
Paddock rotation:	2013 canola, 2014 wheat, 2015 wheat, 2016 wheat
Sowing date	30/5/2014, 12/5/2015, 27/5/2016
Sowing rate	60 kg/ha or 120kg/ha Mace wheat in 2014 and 2015; 50kg/ha or 100kg/ha in 2016.
Fertiliser	80kg/ha Macropro Plus at sowing; 50L/ha Flexi N at maximum tillering stage every season; 35kg/ha sulphate of ammonia in 2016 only.
Herbicides	First knockdown 1-3 weeks before sowing; second knockdown 0-3 days before sowing. At sowing, Sakura 118g/ha on 12/5/2015, trifluralin 2L/ha on 27/5/2016. First post-emergence (PO) herbicide applied at Z13 and second PO herbicide at Z30 of wheat crop each year.
Growing season Rainfall	April to October rainfall: 209mm in 2014; 291mm in 2015; 188mm in 2016.

Table 1: Cumulative effect of chemical and non-chemical weed control options applied from 2014 to 2016 on the 2016 density of wheat heads and, initial and final density of wild radish counted in wheat crop in July and August of 2016 at Dalwallinu, Western Australia[1].

	2014 treatments	2015 treatments	2016 treatments	Wheat heads/ m^2	Initial radish plants/m^2	Final radish plants/m^2
1	Roundup® / Alliance® / 60 kg / no in-crop herbicides / WRB	Roundup® / Alliance® / 60 kg / no in-crop herbicides	Roundup® / Alliance® / 50 kg/ no in-crop herbicides.	203	341.0	70
2	Roundup® / Alliance® / 60 kg / Triathlon® Z13 / Velocity® Z30	Roundup® / Alliance® / 60 kg / Triathlon® Z13 / Velocity® Z30	Roundup® / Alliance® / 50 kg / Triathlon® Z13	234	0.5	0
3	Roundup® / Alliance® / 60 kg / Velocity® Z13 / Triathlon® Z30	Roundup® / Alliance® / 60 kg / Velocity® Z13 / Triathlon® Z30	Roundup® / Alliance® / 50 kg / Velocity® Z13	221	1.0	0.57
4	Para-Trooper® / 60 kg / Velocity® Z13 / Triathlon® Z30	Cultivation / Para-Trooper® / 60 kg / Velocity® at Z13 / Triathlon® Z30	Para-Trooper® / 50 kg / Velocity® Z13 / Triathlon® Z30	234	0.5	0.28
5	Roundup® / Alliance® / 60 kg / Velocity® Z13 / Triathlon® Z30 / HWSR	Roundup® / Alliance® / 60 kg / Velocity® Z13 / Triathlon® Z30	Roundup® / Alliance® / 50 kg / Velocity® Z13	240	1.2	0
6	Roundup® / Alliance® / 60 kg / Velocity® Z13 / Triathlon® Z30 / WRB.	Roundup® / Alliance® / 60 kg / Velocity® Z13 / Triathlon® Z30	Alliance® / 50 kg Triathlon® Z30	242	0.9	0
7	Roundup® / Alliance® / 120 kg / no in-crop herbicides / WRB.	Roundup® / Alliance® / 120 kg / no in-crop herbicide	Roundup® / Alliance® / 100 kg/ no in-crop herbicides.	265	162.0	31
8	Roundup® / Alliance® / 120 kg / Triathlon® Z13 / Velocity® Z30	Roundup® / Alliance® / 120 kg / Triathlon® Z13 / Velocity® Z30	Roundup® / Alliance® / 100 kg / Triathlon® Z13	294	0.6	0
9	Roundup® / Alliance® / 120 kg / Velocity® Z13 / Triathlon® Z30	Roundup® / Alliance® / 120 kg / Velocity® Z13 / Triathlon® Z30	Roundup® / Alliance® / 100 kg / Velocity® Z13	284	0.3	0
10	Para-trooper® / 120 kg / Velocity® Z13 / Triathlon® Z30	Cultivation / Para-trooper® / 120 kg / Velocity® Z13 / Triathlon® Z30	Para-Trooper® / 100 kg / Velocity® Z13 / Triathlon® Z30	315	0.2	0
11	Roundup® / Alliance® / 120 kg Velocity ®Z13 / Triathlon® Z30 / HWSR	Roundup® / Alliance® / 120 kg Velocity ®Z13 / Triathlon® Z30	Roundup® / Alliance® / 100 kg / Velocity® Z13	289	0.7	0
12	Roundup® / Alliance® / 120 kg / Velocity® Z13 / Triathlon® Z30 / WRB	Roundup® / Alliance® / 120 kg / Velocity® Z13 / Triathlon® Z30	Alliance® / 100 kg /Triathlon® Z30	293	0.2	0.28
	P-value			<.001	0.006	<.001
	LSD (5%)			32.9	73.81	10.59

[1] Initial density of wild radish before any treatment in 2014 was 70 plants/m^2; Average wild radish before harvest of wheat in 2014 was 17 plants/m^2; Average wild radish before harvest of wheat in 2015 was 1-3 plant/m^2 in the in-crop treated plots and less than 1 in 2016; / = followed by; HWSR = Harvest weed seed removal at 2014 harvest only; WRB = Windrow burning was performed in April of 2015 only; Herbicide rates: Alliance® 2.5L/ha, Para-Trooper® 1.6 L/ha, Roundup® 2L/ha, Velocity®(Group C+H) 670mL/ha, Triathlon® (Group C+F+I) 1L/ha; *Cultivation* was done in 2015; initial wild radish plants counted on 5 July 2016 after weed emergence but before selective herbicide application at Z13; final wild radish density was counted 7/9/2016 after Z13 and Z30 application of selective herbicides.

Results

Wild radish control

Three years (2014 to 2016) of integrated weed management (IWM) to control wild radish have shown that effective knockdowns (double knock is better than single) and application of effective in-crop herbicides (mixtures from 2-3 modes of action) can significantly reduce this wild radish population (Table 1).

Knockdowns reduced in-crop wild radish by 40-45% compared to the untreated buffer (data not presented) regardless of in-crop herbicide application to control radish in previous years. Although high seed rate increased plant and head density of wheat, this neither affected crop yield, nor influenced radish control in 2014 and 2015. In 2016, a high seed rate increased plant (57%) and head density (31%) of wheat, and also reduced initial density of radish by 52% and final density by 56% (Treatment 1 vs 7, Table 1) but did not affect grain yield of wheat (Table 2).

A combination of single or double knockdowns, radish seed removal or windrow burning, high seed rate, and two in-crop selective herbicides (mixtures of C+H or C+I+F) at Z13 and/or Z30 of wheat crop in 2014 and 2015 reduced the wild radish density to a very low level in 2016 season compared to Treatment 1 or 7 (Table 1).

In 2016, a knockdown followed by only one PO herbicide reduced wild radish density from 341 plants/m^2 (Treatment 1) to less than 1 plant/m^2 in most treatments (Treatments 2-6 and 8-12, Table 1).

Although wild radish density was 70 plants/m^2 in 2014, density of wild radish was poor in 2015 (initial density 10.5 plant/m^2 but 1-3 plant/m^2 before harvest). A high density of wild radish (up to 341 plants/m^2 in no-PO herbicide plots with 50kg/ha seed rate) was recorded in 2016 season. These data once again confirm that long dormancy and persistence of wild radish seed in soil and control failure in the previous season would result in high infestation in the subsequent crop. Effective control of high density wild radish is expected to reduce the soil seed bank significantly.

Results in Table 1 showed that to reduce the impact of radish, it is important to apply double knockdowns (season permitting) and two effective in-crop herbicides (early and late crop growth stages) during the first year and second year. In the third year, one knockdown and one in-crop effective herbicide was enough to control almost 100% of the wild radish. However, in absence of effective in-crop herbicides, radish population will build up to enrich soil seed bank quickly (Treatments 1 and 7, Table 1).

Grain yield and economics

Despite achieving good control of radish and use of all standard agronomic practices, overall grain yield at this site was low. This is probably due to a high level of soil compaction at 100-300mm soil depth (Figure 1). On the average, gross margin was greater at 50kg/ha seed rate (for example, $326/ha in 2016) than 100kg/ha (for example, $298/ha in 2016) mainly due to cost for additional seed (Table 2). Although seed rate did not increase grain yield or gross margin, there was a 56% reduction in final radish density in 2016 at 100kg/ha compared to 50kg/ha (Treatment 1 vs 7, Table 1 and 2). Application of knockdowns and increases in seeding rate reduced radish density by 56%. A high seed rate reduced wild radish density but did not increase screenings. High seed rate did not affect screening of wheat but screenings was high when wild radish was not controlled by an in-crop herbicide in 2014 (Hashem et al. 2015).

Overall grain yield of wheat was the highest in 2015 followed by 2016 and 2014 (Table 2). A high seed rate did not increase wheat grain yield in any year although final radish density was reduced by 56% in 2016 (Treatment 1 vs 7, Table 1). Windrowing at 2014 harvest and windrow burning in April 2015 did not reduce radish density. This is probably because the intensity and duration of fire in small amount of fuels collected on windrows from a 2m wide plot was not effective on radish seed. Radish seed collection at harvest time in 2014 was also not effective as most wild radish pods shattered on the ground before harvest.

Regardless of seed rate, double knockdown followed by application of two PO herbicides (one early and one late) in 2014 and 2015, and then one knockdown followed by one application of effective PO herbicides in 2016 produced the highest gross margin due to higher grain yield in 2016 (Treatment 3, Table 2). One knockdown followed by two applications of PO herbicides also increased grain yield and gross margin in 2015 and 2016 while controlling radish effectively (98-100%) (Treatment 4, Table 2).

This IWM trial has clearly demonstrated that, despite developing resistance to various groups of herbicides, wild radish can be effectively managed by application of knockdowns, application of PO herbicide mixtures and inclusion of non-chemical weed control options such as high seed rate (Hashem et al. 2015, 2016). Effective execution of windrow burning and weed seed removal at harvest time will further improve radish control. This approach of IWM will delay the evolution of herbicide resistance in wild radish, decline soil seed bank and produce greater gross margins.

Conclusions

Knockdown herbicides alone provided 40-45% control of wild radish in absence of PO herbicides in the wheat crop, compared to the untreated control.

Based on the results of the 2014, 2015 and 2016 seasons, double knockdowns and the application of post-emergent (PO) herbicides from diverse mode of action groups (for example, Triathlon® and

Velocity®) provided 90-100% control of wild radish in 2014, 92-100% in 2015, and 99-100% in 2016 (Hashem et al. 2015, 2016). Further success of 100% radish control in subsequent years should deplete the wild radish seed bank further.

Despite achieving higher plant density and higher head numbers of wheat, higher seed rate did not result in greater weed control in the 2014 and 2015 seasons although a significant reduction in wild radish density was recorded in the high seed rate plots in 2016 season. Grain yield did not increase with corresponding increases in seed rate in any season. However, economic analysis of 2014, 2015 and 2016 showed that the gross margin in the high seed rate was always lower than normal seed rate due to additional costs for seed.

Table 2: Effect of chemical and non-chemical weed control options on wild radish control, wheat grain yield, and gross margin in 2014, 2015 and 2016 seasons in the Integrated Weed Management trial for wild radish at Dalwallinu, Western Australia[1].

Treatments	Wild radish control (%)			Wheat grain yield (t/ha)			Gross margin ($/ha)		
	2014	2015	2016	2014	2015	2016	2014	2015	2016
1	93	40	0	1.05	1.96	0.80	216	422	139
2	100	100	100	1.04	1.98	1.75	178	394	354
3	100	100	99	1.09	2.17	2.13	193	445	429
4	98	100	100	1.08	2.23	1.82	217	468	348
5	100	100	100	1.13	1.94	1.67	195	383	335
6	97	100	100	1.08	2.20	1.68	190	451	352
7	90	42	48	0.92	2.00	1.09	117	373	150
8	100	92	100	0.97	2.09	1.67	97	364	310
9	99	100	100	1.03	2.12	1.78	115	372	332
10	100	99	100	0.97	1.99	1.67	124	344	317
11	100	100	100	1.03	2.23	1.94	105	401	381
12	100	100	100	0.99	2.05	1.53	93	351	297
P-value	<.001	<0.01	<.001	<.01	NS	<.001	-	-	-
LSD (5%)	3.6	18.3	2.05	0.084	0.316	0.426	-	-	-

[1] See Table 1 for treatment details in 2014, 2015 and 2016; Windrow burning (WRB) cost (2.05/ha) was included in 2015 variable cost only; cost of HWSR (Harvest weed seed removal) in 2014 only= $10; Price of herbicides ($/ha): Alliance® $25, Roundup®= $14, Para-trooper®= $12, Velocity® =$20, Triathlon® = $15.5: cost of wheat seed = $1/Kg in 2014 and 2015 and $0.3/kg in 2016 assuming that growers used their own seed; Cost of cultivation ($20/ha) is included in 2015 only; In the untreated control (untreated buffer in 2014 and 2015 but treatment 1 in 2016) wild radish density was 70, 10.5 and 341 plants/m^2 in 2014, 2015 and 2016. . Price of wheat grains in December 2016 = $248/t (www.graincrop.co.au).

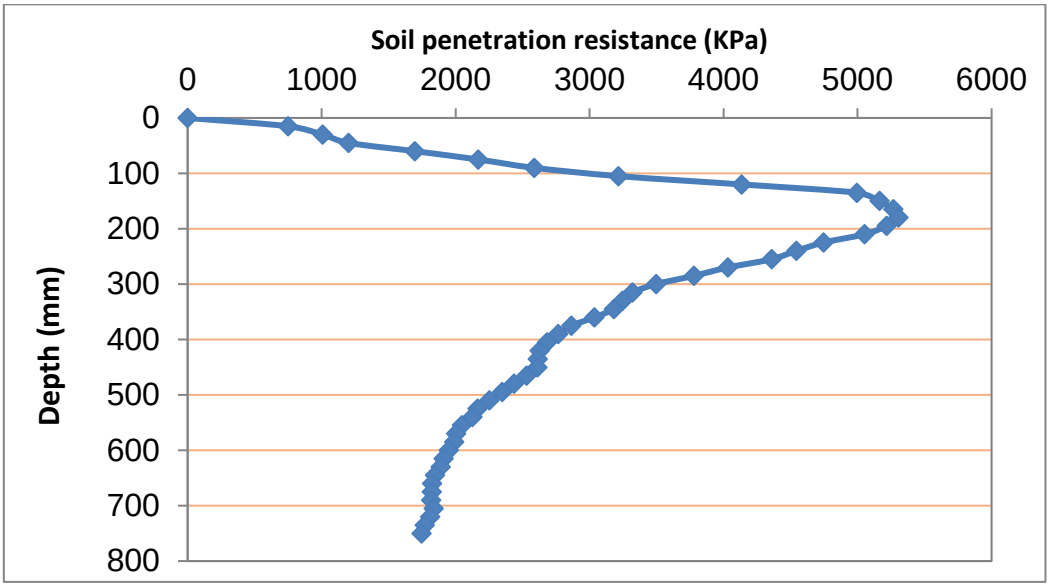

Figure 1: Representative soil compaction level (soil penetration resistance) recorded on 8th September 2016 at the integrated weed management site for wild radish under a canola-wheat-wheat-wheat rotation at Dalwallinu, Western Australia.

These results suggest that herbicides are more cost effective than higher seed rate if radish is effectively controlled by herbicides.

Although expensive, two PO sprays (mixture of 2-3 modes of action) are necessary to achieve 100% control of seasonal wild radish for first couple of years but in the third year (2016), one PO herbicide was enough to effectively control radish. However, if late emergence occurs, a second PO application may be required.

The efficacy of windrow burning could not be studied in this trial due to low intensity and short duration of the burn, as the wheat biomass in the windrows from 2m plots was low. In addition an analysis of trash collected, as an attempt to collect wild radish seed, at 2014 harvest time in treatments 5 and 11 (harvest weed seed removal, HWSR) recorded only few radish seed (0-4 seed per plot of 36 m^2) indicating that wild radish seed had already shattered on the ground prior to harvest in the 2014 season.

The initial wild radish density counted in April 2014 at this site was 70 plants/m^2 while average final density of wild radish in 2015 was reduced to 1- 3 plants/m^2 (95% reduction), due to effective control of radish.

In the 2016 season, the combination of knockdowns and PO herbicides reduced in-crop wild radish from 341 (in the no-PO herbicide plots) to less than one plant/m^2 (Table 1). However, soil compaction at a depth of 100-300mm appears to be a serious constraint to the improvement of grain yield at this site and it is speculated that deep ripping may reduce soil compaction and, in turn, improve crop grain yield.

Wild radish has developed resistance to most of the available selective and non-selective herbicides, including glyphosate, in WA. Application of herbicide mixtures from diverse modes of action at knockdown and post-emergence, together with herbicide rotation, is very important to reduce the risk of herbicide resistance development. This study has shown that wild radish populations can be reduced in a short space of time (3 years) if weed management options, particularly the knockdowns and post-emergent herbicides, are of high efficacy. Other studies on seed rate, row spacing and crop density have shown that such non-herbicide options can be effective against wild radish and should be encouraged at all times to minimise impact of wild radish on crop.

Key words

Integrated weed management, wild radish density, Triathlon®, Velocity®, Para-Trooper®, Alliance®, seed rate, wheat grain yield, economics.

Acknowledgments

This is a collaborative project with University of Adelaide. We are thankful to GRDC for funding the project (UA00149). Thanks are due to Department of Agriculture and Food Western Australia (DAFWA) Technical Support Unit at Wongan Hills. Thanks are due to Technical Officers Dave Nicholson, Barb Sage and Nerys Wilkins for technical assistance. Special thanks are due to Michael Sawyer's Family for providing the land and allowing for access to their farm for the trial, and Liebe Group for their kind collaborations. We also thank Dr Dave Minkey and Leigh Nelson for reviewing the paper.

References

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GRDC Project Number: UA00149