UNDERSTANDING AND MANAGING PROPOSED DIFFERENT DEVELOPMENT STAGES OF HERBICIDE RESISTANCE IN WILD RADISH (RAPHANUS RAPHANISTRUM)

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ABSTRACT

Five stages of 'evolution' or resistance development have been identified in growers' paddocks.
A paddock specific strategy for controlling radish is possible by knowing the resistance genetics present and the stage of resistance development- hence the expenditure required.
We can now describe what is happening within paddocks and can explain why products work or do not work, highlighting the importance of growers knowing what genetics they are dealing with.
Some growers and advisers are apathetic about radish resistance and what is required to farm sustainably into the future.
Best Management Practice is not to rely solely on new chemistries but to use mixtures of both old and new chemistry across populations to minimise selection pressure on all groups.

AIM:

To understand the stages of resistance development within wild radish populations and to develop strategies from a grower's perspective for growing weed free crops in the presence of resistant radish.

TRIAL DETAILS

INTRODUCTION

Nufarm has been working with wild radish for the last 12 years in an attempt to understand the changing genetics of different populations encountered in the West Australian wheat belt. Over this time herbicide resistance has become more widespread and control notably more complex with the rapid loss of base chemistries.

Nufarm previously (GRDC Crop Updates, 2009) proposed, described and quantified the presence of unstacked and stacked* multiple resistance to Group I and Group F herbicides in wild radish populations, providing much needed insight into the type of resistance genetics we are likely to be dealing with in many paddocks. This interaction has not been clearly appreciated. At present, resistance testing continues to focus on single mode of action (MOA) tests while in reality, with multiple resistances, the situation is significantly more complex. As we continue to learn and try to understand the different population dynamics, more questions arise requiring a different focus or direction for research. Most highly problematic populations now require a two-spray strategy with multiple MOA co-mix formulations to achieve satisfactory control during the growing stages of a cereal crop.

The unique biology of wild radish makes it a highly adaptive 'street wise' opponent. It is not only an out crossing species proficient at sharing and spreading genetic change but has complex seed dormancy mechanisms that ensure subsequent germination during a season (and over a number of years) always preserving a portion of its gene pool from particular selective pressures within a crop and different crops over time. This biological complexity highlights the importance of seed bank management.

Over the last four decades radish populations have been exposed to cut-rate, single MOA herbicide treatments unique to the various cropping phases (phenoxies or sulfonylureas in cereals, diflufenican in pulses and triazines in oil seeds) that were never designed to eliminate seed set but simply to achieve an acceptable level of weed control that secured or improved yield. This agronomic approach lead to years of unique herbicidal selection pressures within each of these phases. These uniquely resistant cohorts have constantly enriched seed bank genetics and today coexist as complex mixes of single MOA resistant subpopulations through to truly multiple MOA resistant subpopulations. This is most common where rotations are very narrow (ie wheat, wheat, wheat, pulse producing B and I resistance) or continuous (wheat, pulse producing B, I and F resistance). In these rotations resistance to any one herbicide group is likely to have developed independently but eventually through interbreeding individuals resistant to more than one herbicide group have been produced. The heart of the problem with these populations that have multiple resistances, unstacked and stacked, is the complex mixing and layering of genetics created with every crop over a long time, and it becomes difficult to know what genetics you are dealing with. Whilst this paper focuses on herbicide management, ultimately the erosion and running down of seed banks with a truly Integrated Weed Management approach is the only way of eliminating some very special resistance genetics, otherwise the evolutionary process continues.

*(Stacked resistance: a form of multiple resistance where plants in a population independently develop resistance to herbicides with a different MOA and then through co-existence eventually interbreed to produce individual plants resistant to more than one herbicide group. Diebold. S and Tardif. F, 2006)

Early Background Work

When phenoxy resistance was first discovered in Western Australia in 1999, SU Group B resistance was an established issue. It was only then that extensive research was conducted in the field by Nufarm, initially focusing on phenoxy chemistry. In conjunction to this work, other modes of action used in co-mixed products were also looked at individually and in their commercial co-mix forms with dose response work in resistant populations. These being;

- i) Group B: SU, SA and IMI
- ii) Group F: in EC and non-EC formulations
- iii) Group C: ie bromoxynil
- iv) Group I: phenoxies in MCPA and 2,4D in amine and ester formulations
- v) Group G
- vi) Group O- in recent times
- vii) Co-mixes- BI, BCI, FI, FC, FCI, OI, GI etc.

What appears evident is that while phenoxy resistance likely developed over a long period of time it has probably accelerated following the demise of the widely used SU Group B herbicides, given that this would have placed a strong selection pressure directly on the phenoxies. Interestingly, phenoxies were classified a low risk group to resistance.

Knowledge learnt from these investigations:

- a. Phenoxy chemistry is standard in almost all co-mix products used in winter cereals today and must be effective or the other mode or modes of actions are compromised resulting in poor efficacy. Product examples include Broadside®, Bromicide MA®, Group G and O chemistry co-mixed with phenoxies.
- b. Whilst bromoxynil is a synergistic mixing partner, when the other component(s) start to break then these mixes start to fail ie. Jaguar®, Bromicide MA®.
- c. When combating herbicide resistance with multi-MOA mixes the individual components of these mixes must be at lethal rates.
- d. The need to protect and ensure continued effectiveness of the ‘older’ MOA mixes

Evolution-quantifying different paddock resistance profiles

Nufarm has conducted 151 individual trials over 89 sites in Western Australia since 2000; an average for the last 6 years of 12 sites and 21 trials per annum. These have been predominately located in the Northern and Central wheat belt, although a number have been conducted in the Great Southern and South Eastern regions where problems are escalating. Recent AHRI resistance surveys confirm that wild radish resistance is no longer localised to the northern regions but is now a state wide issue with Group B, I and F resistance identified throughout.

This large data set has allowed analysis across many paddocks and by studying and grouping similar responses to herbicide treatments has presented a unique opportunity to categorise population genetics into a number of defined stages (designated as RRD Stages, or Radish Resistance Development Stages). These stages purely reflect the time these paddocks have been farmed and the herbicide regimes they have been exposed to. These RRD Stages track the evolution from single MOA resistance through multiple unstacked MOA resistance to multiple stacked MOA resistance in populations with a very complex mix of these resistances. What transpires is a progressive loss in ability to control the species to a point where the extreme ‘stacked’ plants are dependent solely on new chemistry to achieve satisfactory control. Best Management Practice is not to rely solely on these new chemistries, however, but to use mixtures of both old and new chemistry across a population to minimise selection pressure.

The following RRD stages of resistance development are proposed to essentially describe the evolution of resistance according to the biology of the radish plant and define what is required for management:

RRD Stage 1: Truly susceptible populations.

All chemistries registered for use on wild radish perform as well as they did at their development.

RRD Stage 2: Partially susceptible populations.

All registered chemistries still control wild radish and there are no overt signs of resistance, yet there are a number of clear indications suggesting that control is being impacted. For example: the gap between the performance of esters and amines has widened, there is a longer kill time (once 2/3 weeks now to 6/8 weeks plus) and there is a need to spray earlier on smaller weeds for effective control.

Effective control of RRD Stage 2 with one spray currently from $14, ideally with two sprays from $21 to $27 per hectare.

RRD Stage 3: Populations overtly resistant to individual MOA only.

Obvious resistance to a single herbicide group, be it Group B, I or F, or evidence of multiple Group B, I and F resistance, but no stacking. Using a full label rate, two-way MOA mixture and especially adding a third MOA to the treatment will give consistent robust weed control.

Effective control of Stage 3 can range from $21 to $27 per hectare based on current costs.

RRD Stage 4; High level of individual MOA resistance with the 1st stages of stacked multiple resistance.

Group B's largely non-functional and multiple Group I and F resistance with low levels of stacking. Given SU Group B resistance has now been present for 20 years; both I and F subpopulations have likely stacked with resistant B subpopulations. The only option is for growers to use a three-way MOA treatment with all actives at full label rates, or to introduce alternative chemistry. The adoption of a two spray strategy is imperative, due to seed bank issues.

Effective control of Stage 4 can range from $44 to $55 per hectare based on current costs.

RRD Stage 5: High levels of stacked multiple resistance, three-way MOA treatments with existing chemistry not effective

Group B's are non-functional, with multiple Group B, I and F resistance at moderate to high levels of stacking. Growers must use a third MOA with all actives at full label rates and must use a two and possibly a three spray strategy: i) FIC early followed by H, ideally HCI or ii) Group HC followed by Group HCI iii) Late Roundup in crop needs to be factored in.

Effective control of Stage 5 is $59 plus per hectare based on current costs.

Beating Incremental Change in Resistance Genetics

The proposed incremental change or shift in resistance observed with time suggests that populations become enriched with resistant genetics following continual use of the same modes of actions. From the perspective of growers and advisers this challenges the concept of making slow incremental changes as resistance slowly gets 'worse'.

Fundamental errors made that severely impact the advances of resistance include:

i) Compromised recommendations. Utilising less than full label rates due to spending bias, and based on 'susceptible' virgin genetics due to a lack of knowledge of the target population.
ii) Late spraying on larger plants in trying to limit operations to one spray only.
iii) The continued use of a broken MOA putting undue selection pressure on the partner MOA in any co-mix
iv) Relying on 'Additive' or 'Synergistic' herbicide interactions: These interactions generally no longer apply once resistance develops to the primary active.
v) Accepting some survivors and not understanding that the biology/dormancy/out crossing moves these resistance genetics within a population, as well as builds a seed bank.
vi) Current resistance testing is ONLY single MOA based and does not test true population genetics
vii) Inappropriate collection of seed for a resistance test that presents a bias from the true population
viii) Apathy and poor attitude to change with radish resistance and what is required to farm sustainably into the future.

Insanity- is to keep doing what you have always done, or shoot in the dark and blame the bullet when the target is missed

Impact on farm profitability

One of the most important factors to understand is that whilst not all plants within a population have resistance genetics, it is actually the resistant ones that should govern what is spent as these plants are the ones that must be managed. With long dormancy and seed viability (6-8+ years) the impact of missed opportunities and resistance genetics creates long term expenditure and management!

The lesson learnt from working in the 'worst of the worst' RRD Stage 5 populations in the cereal phase is that effective control currently costs a minimum of $59 upwards, and where a third spray is required an additional $30. This direct cost is NOT negotiable. Many of these paddocks are in the low rainfall, low yield regions, where this amount must still be spent to remain viable. Prior to the new Group H chemistry a number of these paddocks were no longer cropable in respect to any sort of weed control as there was no effective MOA available, thus they had essentially become a zero land asset. If these populations are not managed correctly going forward using new chemistry, adopting zero seed set by whatever means, and incorporating as many IWM practices as possible, a disaster is imminent. These populations currently are placing massive selection pressure on Group H with a high probability of paddocks again becoming non-cropable should the chemistry be lost.

RRD Stage 5 paddocks developed over a ten to maximum fifteen year period from poorly managed RRD Stage 3 and 4 scenarios, which in-turn came from RRD Stage 2 type paddock populations

With RRD Stage 3 and 4 resistances, the immediate impact on herbicide expenditure, where the phenoxy group is not functional, currently adds from $22 to $30 per hectare to standard options, and again this is not negotiable! These paddocks developed from RRD Stage 2 resistance over the relatively short period of 10 to 15 years.

Furthermore, it has also recently been recognised that there is a hidden impact of phenoxy and group B resistance on the performance of knockdown mixes where they are routinely included to bolster broadleaf control. This cannot be underestimated though is not directly part of this paper.

There are many Western Australia growers who have experienced resistance issues and have been forced to adopt diverse management practices to 'recover' paddocks and secure sustainability into the future. These include weed seed management at harvest, burning, mouldboard ploughing, rotations, fallow, hygiene etc. which all add to expenditure in their own right. The WA Department for Agriculture and Food has monitored grower practice and has clearly recorded 'the big picture whole farm integrated' approach as the only sustainable system. A complete herbicide only approach is just not sustainable.

Attitude to change

Some growers and advisers are apathetic about radish control basically through not wanting to understand or be proactive. A description of what is happening in the paddock is now documented, the mistakes and how they were created is described, and short and long term management strategies required to combat the problems defined, but one of the biggest resistances is attitude to adopt and to change. Until recently, preconceived ideas and biases by advisers and growers on dollar spend, management and commercial influences have largely created these situations. It is possible to learn, if willing, from the growers who have experienced major issues in the past and thus avoid a lot of expense and lost income.

The absolute positive to come from working with Western Australia growers over this period is their positive attitude to accepting that there are issues and that resistance is evolving but whilst facing adversity they want to learn and benefit fellow growers. Without this transparency and trial work, being open about what is happening in their own paddocks, especially with 'hit the wall' paddocks, other Australian growers would not benefit. The majority of growers when they have an understanding of what is happening in their paddocks are extremely adoptive to change and appreciative knowing what to do.

2012 Trial work

Methods

2012 trial work was designed to quantify the genetic fingerprint of four radish populations, to determine and explain why specific treatments either worked or did not, and then to determine what effective herbicide regime was required by the grower for effective control in these paddocks.

The work was conducted on populations at Yuna, Morawa, Carnamah and Watheroo where large seed banks existed and previous control had been compromised (thought to be due to resistance). Trials were sprayed by hand boom at 75 L water/ha, over 11 x 2 metre plots with 3 randomised replications.

The design of each site was formulated from previous in-situ work which consisted of 3 sections

i) Single MOA dose response screening (Part 1)
ii) Standard post emergent options that growers can use (Part 2)
iii) Sequential spray options that growers can use (Part 3)

Radish growth stages at Time of Spraying 1

Yuna: 27th June; 2 leaf (4 to 6cm dia), density 100 to 500 per sqm, occasional 7-8 leaf (35cm dia), density 0.1 per sqm.
Carnamah: 2nd July; 5% Cots, 45% 2 leaf (3-5cm dia), 40% 3-4 leaf (7-10cm), 10% 5 leaf (12-14cm dia), density 2-4 leaf up to 30-40 per sqm.
Watheroo: 20th July; 80% Cot-2 leaf (8cm dia), 20% 4 leaf (8-12 cm dia), density 0 to 120 per sqm.
Morawa: 19th July; odd cot, 3 leaf (<5cm dia), 7 leaf (10cm), 7 leaf (25-30cm dia), density 1 to 15 per sqm, highest 25 to 60 per sqm, ave 5 to 8 per sqm.

Results:

Part 1: Herbicide resistance screening

Screening base chemistry is considered essential to the study as it provides a clear indication of the genetic fingerprint of each population allowing a better understanding and interpretation of the contribution that each group makes to the multi MOA mix treatments of Parts 2 and 3.

Based on Part 1 screening the assumed resistance status of each of the four populations is shown in Table 1. At all sites there were various degrees of resistance shown to all MOA groups tested. None of the populations were found to be sensitive to any of the three herbicides groups tested, even at elevated rates, but this could be expected given that sites were selected on the basis of having problematic wild radish.

Table 1. Categorisation of herbicide resistance status of wild radish populations in field studies in 2012

Mode of Action Group	I	I	SU	SU	Immi	Immi	SA	SA	F	F	F	F
Site	Ester680 800mLs	Ester 680 1.6L	Ally® 5gms	Ally ®25 gms	Spinnaker® 70gms	Spinnaker® 280gms	Eclipse® 15gms	Eclipse® 60gms	Brodal ®200mLs	Brodal ®400mLs	DFF/PLF 25gms EC	DFF/PL 50 gms EC
Yuna: 2012	RR	S	RRRR	RR	RRR	R	RRRR	RRRR	RR	R	NT	NT
Carnamah: 2012	RRRR	RRRR	RRRR	RRRR	RRR	R	RRRR	RRRR	NT	NT	RR	R
Watheroo: 2012	RRR	RRR	RRRR	RRRR	RRRR	RR	RRRR	RRRR	RRRR	RRRR	RRR	RR
Morawa: 2012	RRRR	RRRR	RRRR	RRRR	RRRR	RRRR	RRRR	RRRR	RRRR	RRRR	NT	NT

% Control Category: S* = 100%, R* = 90-99, RR* = 80-89, RRR* = 70-79, RRRR =>70. NT- Not Tested

Categories are an arbitrary judgement based on the degree of deviation from expected level of control, and the performance at elevated rates of herbicide.

Part 2: Radish control with standard Post Emergent options available

This section involves looking at the performance of standard early post emergent options sprayed when the crop was (ideally) Z1.3-Z1.5 and radish plants were small. The results shown in Table2 demonstrate the interaction of the individual modes of action resistances present.

Table2: Radish control with standard Post Emergent options available

	Final Rating	49 DAT	38 DAT	59 DAT	47 DAT
Post-em Treatment	M of A	Yuna	Carnamah	Watheroo	Morwawa
LVE Agritone ® 440mLs + Monza 25gms + Bonza 1%	I B	85	5	73	78
Minder® 1L	F C	99	93	90	80
Paragon® 375mLs	F I	99	63	82	76
Flight® 540 mLs	F I C	98	94	92	80
Paragon® 500mLs	F I	99	85	84	68
Flight® 720mLs	F I C	99	98	99	85
Velocity® 670 mLs + Hasten 1%	H C	100	100	95	98
Precept® 300 1L + Hasten 1%	H I	100	97	96	98
Precept® 300 1L + Ecopar 400mLs + Hasten 1%	H I G	n/a	99	97	90
Ecopar® 400 mLs + 330 Agritone 750® (MCPA Amine)	G I	65	13	55	33
Affinity® 50 gms + 330 Agritone 750® (MCPA Amine)	G I	70	13	52	33
Stacking level	B I	Moderate	Extreme	High	High
	F I	None	Moderate	Moderate	High

Part 3: Sequential Spray Program

Sequential spraying regime- understanding why and what it involves?

Sequential sprays in crop are now standard practice in most regions, especially where moderate to high seed banks exist - due to plants germinating later in the crop. These avoid the standard earlier post emergent spray program. The critical factor with sequential sprays is to achieve absolute control thus preventing seed set and hence preventing any new resistant genetics going back into the seed bank. It can be debated which spray is the most important, as ensuring complete control with the first spray can be problematic. Ultimately, they are both as important as each other and they should complement each other. It can be argued the second is more critical, as it should control resistant survivors from the first spray as well as controlling subsequent germinations.

Several major issues arise though. With phenoxy resistant populations, the standard second 2,4-D spray is no longer an effective option, and thus Group H must be used as the second spray given that Group F is typically injurious as a late spray. The problem is that Group H is promoted as an early spray treatment, though in 'Stage 5' populations it can be the only effective MOA left, raising the prospect of two Group H treatments in the same year and the question of how sustainable this is in the long term. The use of some of these products later and outside their registered application windows can also create residue issues.

The objective of a sequential two spray regime using registered herbicides is twofold;

i) to control any subsequent germinations due to dormancy, and,
ii) to control any survivors of the first spray due to resistance, numbers, coverage or rate for size issues.

The rules of engagement adopted in this trial work are based on the following considerations:

1. All sprays go out on small weeds (as early as possible): ideally the first spray at Z1.2 – 1.3 of the crop with the second spray 3 to 5 weeks later in the northern regions, or 4 to 7 weeks in southern regions based on temperature and rate of growth.
2. Understand that Group H has limitations and is not always 100% effective when large numbers of radish are present, leaf shading is an issue, plants are too large and where Group I resistance is present. Group H needs to be used within its chemistry parameters
3. All actives used at full label rate as identified by previous published work when multiple resistance is present.
4. Include phenoxy as a standard third MOA, regardless of the level of resistance. As a base third MOA adds to and assists with susceptible plants where translocation is compromised in thick canopy crops where coverage with Group H is an issue

Table 3: Sequential spray program results showing the average percent control of Wild Radish 4 to 5 weeks after sequential (second) herbicide treatments.

All radish populations had medium to high levels of Group B, F and I resistance, unstacked and stacked. These data are based on 4 sites x 3 replications, plant numbers ranged from 100-300 per sqm at timing 1 (Cot-6 leaf) and 10-50 per sqm at timing 2 (Cot-2 leaf plus surviving plants from the first spray treatments). The first spray treatment was applied 3-5 weeks after sowing and sequential treatments 3-7 weeks after first spray treatments.

				Yuna	Carnamah	Watheroo	Morawa
				at 15th Aug	at 18th Sept	at 18th Sept	at 5th Sept
	Final Assesment			49 DAT 1, 28 DAT 2	77 DAT 1, 38 DAT 2	59 DAT 1, 28 DAT 2	47 DAT 1, 26 DAT 2
1st Spray	**2nd Spray**	$/ha	M of A	Ave	Ave	Ave	Ave
Minder® 1L	**nil**	**14**	**FC/-**	**98**	**88**	**90**	**87**
Minder® 1L	Ester 680 800mLs	21	FC/I	100	100	90	92
Minder ®1L	Velocity® 670mLs + Hasten	41	FC/HC	98	100	100	100
Minder ®1L	Velocity® 670mLs + Ester 680	46	FC/HCI	100	96	100	100
Paragon® 500mLs	**nil**	**12**	**FI/-**	**100**	**95**	**90**	**83**
Paragon® 500mLs	Ester 680 800mLs	17	FI/I	100	95	90	93
Paragon® 500mLs	Velocity® 670mLs + Hasten	39	FI/HC	100	100	100	98
Paragon® 500mLs	Velocity® 670mLs + Ester 680	44	FI/HCI	100	100	100	100
Flight® 720mLs	**nil**	**20**	**FIC/-**	**100**	**100**	**95**	**91**
Flight® 720mLs	Ester 680 800mLs	25	FIC/I	100	100	97	96
Flight® 720mLs	Velocity® 670mLs + Hasten	47	FIC/HC	100	100	100	100
Flight® 720mLs	Velocity® 670mLs + Ester 680	52	FIC/HCI	100	100	100	100
Velocity® 670mLs + Hasten 1%	**nil**	**27**	**HC/-**	**100**	**100**	**95**	**98**
Velocity® 670mLs + Hasten 1%	Ester 680 800mLs	32	HC/I	100	100	100	100
Velocity® 670mLs + Hasten 1%	Velocity® 670mLs + Hasten	54	HC/HC	100	100	100	100
Velocity® 670mLs + Hasten 1%	Velocity® 670mLs + Ester 680	59	HC/HCI	100	100	100	100

General Discussion

All of these populations (Table 2) showed poor performance to the standard LVE MCPA + SU Group B as evidenced by the high degree of resistance to SU Group B and various levels of phenoxy resistance (ie. these survivors are stacked multiple resistant). Interestingly there was also a moderate to high level of resistance to the SA and IMI chemistry (Table 1). Due to phenoxy resistance the Group G products, Ecopar® and Affinity®, were not efficacious. Precept® with Ecopar®, an off label occasionally recommended treatment caused unacceptable crop effects and did not significantly improve control, and at the extreme phenoxy resistant Morawa site was antagonistic. These results confirm earlier work by Nufarm and Ag WA, 1996, that Group G chemistry must have an effective phenoxy partner to perform satisfactorily so they are not a viable option in phenoxy tolerant populations.

Site-specific observations:

Yuna: this site presents a relatively easy population to control as seen by the lower degree of resistance to Group I (RR) and Group F (RR) and no obvious indications of 'stacking'. The standard full rates of FC, FI, FCI, HC and HI all performed well. The population fits RRD Stage 3 where screening data indicates there are no recommended MOA limitations for either the first or second spray operations. While the options available for the first spray are many and varied there is a concern regarding the effectiveness of a phenoxy in the second spray given the level of tolerance noted to Group I, and thus the recommendation is that both sprays be multiple MOA co-mixes.

Carnamah: has a very high level of phenoxy resistance (RRRR) and a low to moderate level of F (RR) and demonstrates stacked FI resistance with 15 percent survival of the full rate. The standard full rates of FI and FC and the low rate of FCI did not give complete control and there were also occasional surviving plants to the full rate FCI as well as to Precept (HI). The site was unique in having extreme BI stacking. This population is subtly different from Watheroo with higher I but lower F individual resistances, even though the level of stacking is similar. The population fits RRD Stage 4 from a resistance development classification and could possibly be considered borderline RRD Stage 5. It requires a multi MOA two spray operation for complete control and where a phenoxy cannot be used as a second spray option and must contain Group H. Ideally from a resistance and herbicide rotation management perspective the first spray should be FCI and the second contain Group H, ideally a HCI spray.

Watheroo: has very high levels of phenoxy resistance (RRR) and Group F (RRRR) and truly demonstrates stack FI resistance in 16% of the population screened. Morawa: has extreme levels of resistance to all base chemistries and demonstrates stack resistance of 32%. Whilst these populations appear similar, the subtle difference with Morawa is the greater portion of plants in the total population with individual MOA resistance and a higher stacked resistance. Both these populations require a 2 spray sequential regime for complete control. Again, phenoxy cannot be used as a second spray option, it must contain Group H. Both populations typically fit RRD Stage 5

RRD Stage 5 type genetics presents a dilemma in that it probably requires two Group H applications for effective control, which from a resistance management perspective may not be sustainable in the long term and extremely risky. Whilst complete control was achieved by a weakly performing first spray of FIC followed by HC/HCI, the strategy is challenging as it relies on getting all aspects of the second spray correct for complete control. This work demonstrates the difficulties with managing and controlling RRD Stage 5 genetics. These two populations pose considerable challenges and questions whether these types of paddocks can be farmed long term if the extreme genetics are not removed from the seed bank.

Summary and Conclusions

These results define and show the complex herbicide resistance interactions that are occurring in Western Australian paddocks, especially in northern and central parts of the wheat belt. They provide valuable insight into the proposed RRD Stages 3, 4 and 5 type genetics and what is required to give complete control with these groups. Whilst these complex genetics were first noted in the northern parts of the wheat belt they are by no means confined to this region currently and importantly send a clear message to growers and advisers across Australia.

The loss of the phenoxy chemistry, a base MOA in most herbicides will add an additional $22 per hectare and where stacked resistance occurs the total expenditure can be upwards of $59 per hectare

This work highlights the need to know the resistance status of the whole population and offers a challenge for new testing procedures for stacked resistances. It is imperative to adopt 'a multi mode of action, don't tolerate any seed set' approach on all populations, but especially on populations that are still relatively sensitive (Stage 1 and 2), this way it will significantly retard the advent of resistance especially when incorporated with a sound IWM approach.

The big message for advisers and growers is manyfold: resistance testing, a thorough understanding of why and how radish became problematic in any one paddock, a thorough appreciation that the seed bank must be managed and a zero seed set policy adopted are all essential components to combating wild radish. General farm hygiene is also an important component. It is a large and complex subject that needs investment in extension but most importantly, key players need to be open to learn and adopt.

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