The use of carfentrazone-ethyl to aid in the knockdown of difficult to control broad leaved weeds

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Summary Carfentrazone-ethyl has been evaluated for use as a mixing partner for the knockdown herbicides glyphosate and paraquat with the objective of increasing both the reliability of broadleaf weed control and the speed of activity.

Carfentrazone-ethyl has shown a high degree of activity on some of the harder-to-control broad leaved weeds such as marshmallow (*Malva parviflora* L.), Paterson's curse (*Echium plantagineum* L.) and subclover (*Trifolium subterraneum* L.). In addition, doublegee (*Emex australis* Steinh.) and the brassica species, particularly wild radish (*Raphanus raphanistrum* L.), which are showing increasing levels of Group B herbicide resistance, have also been well controlled.

The 2002 winter cropping season will see the launch of carfentrazone-ethyl in a 240 g a.i. L^{-1} EC formulation branded as Hammer EC by FMC (Chemicals) Pty Ltd and distributed in Australia by Crop Care Australasia Pty Ltd specifically for use as a mixing partner with the major knockdown herbicides.

Carfentrazone-ethyl has many unique benefits, however one of significant interest to the farming community is that it has no soil carryover and therefore no plant back restrictions – a particular benefit when using prior to sowing legumes or oilseeds.

Keywords Carfentrazone-ethyl, glyphosate, broad leaved weeds, knockdown herbicides.

INTRODUCTION

Herbicides control plants by disrupting different functions of the plant cell. Carfentrazone-ethyl is a light-dependent herbicide that inhibits the enzyme protoporphyrinogen oxidase (commonly abbreviated as protox) and in doing so, disrupts lipid and cell membranes. The lethal effect is caused by natural plant compounds that accumulate in the cells of weeds treated with carfentrazone-ethyl. Protox is the site of action, but induction of lipid peroxidation, which results in membrane disruption, is the mechanism of action. Membrane disruption is the overall mode of action.

The following points summarise the protox mechanism of, and course of action for, carfentrazone-ethyl in plants:

- Sunlight and photosynthesis are required. Light is required for activity since photosynthesis must be in progress. Newly developing leaves, actively making plant pigments, are most susceptible.
- Protox inhibition leads to a build-up of protoporphyrin IX, an intermediate in chlorophyll synthesis.
- In light, protoporphyrin IX is very efficient at transferring energy to oxygen-yielding, unstable forms including singlet oxygen.
- The cell membrane is damaged, releasing cell contents into intercellular spaces, causing the cell to collapse and die.
- Cellular destruction results in plant tissue necrosis (death).

The process and onset of action is very rapid. Plants treated with carfentrazone-ethyl become necrotic and die shortly after treatment. Initial symptoms are observed within 3–4 days and mortality occurs within 10–14 days under ideal conditions.

Leaf penetration is the key to control with carfentrazone-ethyl and weeds should be in an active growth stage – producing chlorophyll – to maximise effects.

MATERIALS AND METHODS

A series of eight trials were conducted in the Western Australian wheat belt (Moora and Gnowangerup districts) in the 2001 season to evaluate the efficacy of carfentrazone-ethyl when mixed with glyphosate and applied prior to crop establishment or as fallow sprays. The weed species targeted were marshmallow, subclover, Paterson's curse, wild radish and doublegee.

All trials were of a complete randomised block design with three replications and plot dimensions of 3 × 10 m. Treatments were applied by means of an LPG plot sprayer with an output of 60 L ha^{-1} using 11001 Teejets at 200 kPa. The rate of glyphosate (450 g a.i. L^{-1}) used ranged from 600 mL to 1000 mL ha^{-1} dependent on weed size. The rate chosen was always as close as practical to the minimum required, to ensure that the glyphosate did not mask any of the rate responses from the mixing partner herbicides. A two times rate of glyphosate was also used to evaluate each species general susceptibility to glyphosate alone.

Visual assessments of percent control were made at 7 and 14, days after application (DAA), final weed counts were performed at 40 DAA to ensure sufficient time for any re-growth to have occurred.

The results presented below are the average of one to three data sets and thus statistical analysis has only been included for single data sets.

At the time of application the broadleaf weeds ranged in size from cotyledon to 6-leaf. This was considered to be typical of weed sizes at crop establishment.

RESULTS

Whilst no grass species results are presented, most sites had either annual ryegrass (*Lolium rigidum* Gaudin) or barley grass (*Hordeum leporinum* Link) present ranging in size from Z12 to Z21. There was no evidence of carfentrazone-ethyl having any activity on the grass species present. These grasses were totally controlled by all treatments with symptoms typical of glyphosate use.

The use of both carfentrazone-ethyl and oxyfluorfen resulted in rapid leaf desiccation and increased speed of death of the target broad leaved weeds. Both carfentrazone-ethyl and oxyfluorfen significantly increased the speed of control at 7 DAA, compared to glyphosate alone. Carfentrazone-ethyl was noticeably quicker acting than oxyfluorfen on all specials tested with the exception of wild radish, where it was equivalent to oxyfluorfen.

DISCUSSION

Table 1 and 2 Marshmallow is well known to be difficult to control with glyphosate at commercial field rates. This was borne out in these trials where a two times field rate was tested and gave less than 45% control (results not shown).

Marshmallow has proven very susceptible to carfentrazone-ethyl and its use has resulted in quicker brownout and a higher level of final weed control than the standard oxyfluorfen.

Carfentrazone-ethyl at 12 to 18 g a.i. ha^{-1} achieved virtually 100% control, even of some very large and mature plants as seen in Table 2.

The higher rate of oxyfluorfen (30 g a.i. ha^{-1}) has shown clear antagonism compared to the lower rate (18 g a.i. ha^{-1}) on the young marshmallow plants Table 1, from the 14 DAA assessment onwards. The higher rate resulted in initial rapid desiccation, at 7 DAA, followed by re-growth clearly apparent at 14 DAA and increased numbers of surviving plants at 40 DAA compared to the lower rate of oxyfluorfen.

The reduction in efficacy at 7 DAA from the higher oxyfluorfen rate in Table 2 can not be explained. There was again clear evidence of re-growth at 14 DAA for the higher rate of oxyfluorfen, that was not evident for the lower rate.

Table 3 Subterranean clover can be difficult to control with glyphosate particularly when it is very small at the cotyledon to 2-leaf growth stage. Whilst it does respond well to increased rates of glyphosate a more reliable method of control is by using various tank mixtures with glyphosate.

As a species, subterranean clover is slower to respond to carfentrazone-ethyl than some other broad leaved species as can be seen from the seven day assessment. However, by 14 DAA virtually full control was achieved. The final level of subterranean clover control achieved was markedly better with the addition of carfentrazone to glyphosate compared to glyphosate alone, with a clear numerical rate response.

Whilst oxyfluorfen was only slightly behind carfentrazone-ethyl at 14 DAA, final plant counts revealed a markedly higher level of plant re-growth and survival in the oxyfluorfen treatments, compared to carfentrazone-ethyl. The final level of control achieved by oxyfluorfen plus glyphosate was similar to glyphosate alone.

Table 1. Marshmallow (*Malva parviflora*), average three trials, plants 4 weeks old, (cotyledon to 8 leaf).

Treatment	Rate g a.i. ha^{-1}	Visual % control 7 DAA	Visual % control 14 DAA	Plants m^{-2} 40 DAA
glyphosate	270	8	24	66
+ carfentrazone	6	85	90	9
+ carfentrazone	12	94	93	2
+ carfentrazone	18	95	94	1
+ oxyfluorfen	18	79	88	4
+ oxyfluorfen	30	87	80	14
Untreated				78

Table 2. Marshmallow (*Malva parviflora*), one trial, plants 4 months old, (15–30 cm diameter).

Treatment	Rate g a.i. ha^{-1}	Visual % control 7 DAA	Visual % control 14 DAA	Plants m^{-2} 40 DAA
glyphosate	450	10	15	16
+ carfentrazone	6	82	83	2
+ carfentrazone	12	92	86	1
+ carfentrazone	18	93	93	0
+ oxyfluorfen	18	85	88	1
+ oxyfluorfen	30	75	62	2
Untreated				29
LSD (P=0.05)		14	24	8

Table 3. Subterranean clover (*Trifolium subterranean*), average three trials, plants 4 to 6 weeks old (cotyledon to 4 leaf).

Treatment	Rate g a.i. ha^{-1}	Visual % control 7 DAA	Visual % control 14 DAA	Plants m^{-2} 40 DAA
glyphosate	360	9	78	30
+ carfentrazone	6	42	98	13
+ carfentrazone	12	58	100	7
+ carfentrazone	18	66	100	3
+ oxyfluorfen	18	30	98	26
+ oxyfluorfen	30	48	97	32
Untreated				103

Table 4 Paterson's curse responded well to the addition of carfentrazone-ethyl. Paterson's curse has proved to be markedly more susceptible to carfentrazone-ethyl than oxyfluorfen, with greater speed of desiccation at 7 and 14 DAA and a higher level of final weed control 99% versus 90%. The final level of control achieved by oxyfluorfen plus glyphosate was numerically inferior to glyphosate alone. Suggesting some level of antagonism with the mixture.

Table 5 Wild radish responds well to glyphosate but a mixing partner is often required to ensure total control. The use of carfentrazone-ethyl as this mixing partner helped to ensure the highest level of control possible and provided a better result than oxyfluorfen. The final level of control achieved by oxyfluorfen plus glyphosate was similar to glyphosate alone.

Table 6 Doublegee also proved to be quite susceptible to glyphosate. The main benefit to the use of carfentrazone-ethyl is the speed of desiccation and death that is achieved within seven days of application. The final level of control achieved by oxyfluorfen plus glyphosate was similar to glyphosate alone.

CONCLUSION

All broad leaved weeds tested in this series of trials proved to be susceptible to carfentrazone-ethyl.

All species, with the exception of marshmallow, responded well to the two times rate of glyphosate. However, a more reliable method of control was provided by the addition of carfentrazone-ethyl to glyphosate.

Whilst the base glyphosate rate used in these trials was selected to ensure that there was no masking of any rate responses to the mixing partners, common field use rates of glyphosate would have typically been at 45 to 90 g a.i. ha^{-1} higher than those used, this would again provide additional robustness to the results achieved.

There was no evidence of any antagonism between glyphosate and increasing rates of carfentrazone-ethyl in these trials.

However, there was a common trend for a numerical inverse rate response to the use of oxyfluorfen. This was particularly evident for the young marshmallow (Table 1). This is a commonly observed field experience where rates of oxyfluorfen (24 g a.i. ha^{-1} or higher) are used with glyphosate rates of 450 g a.i. ha^{-1} or less. It is the opinion of the author that if a high enough rate of oxyfluorfen is combined with a low rate of glyphosate then the movement of the glyphosate to its sites of action can be reduced, resulting in initial foliage desiccation from the oxyfluorfen followed by new growth emerging from the lower growing points. Further work may be warranted to fully understand this issue.

Table 4. Paterson's curse (*Echium plantagineum*), one trial, plants 4 weeks old, (3 to 6 leaf).

Treatment	Rate g a.i. ha^{-1}	Visual % control		Plants m^{-2} 40 DAA
		7 DAA	14 DAA	
glyphosate	360	5	18	6
+ carfentrazone	6	23	78	4
+ carfentrazone	12	53	84	0
+ carfentrazone	18	83	92	2
+ oxyfluorfen	18	12	64	12
+ oxyfluorfen	30	15	75	18
Untreated				134
LSD (P=0.05)		12	14	15

Table 5. Wild radish (*Raphanus raphanistrum*), one trial, plants 4 weeks old, (3 to 4 leaf).

Treatment	Rate g a.i. ha^{-1}	Visual % control		Plants m^{-2} 40 DAA
		7 DAA	14 DAA	
glyphosate	360	10	70	13
+ carfentrazone	6	23	97	6
+ carfentrazone	12	25	96	3
+ carfentrazone	18	30	99	1
+ oxyfluorfen	18	17	88	10
+ oxyfluorfen	30	28	95	13
Untreated				135
LSD (P=0.05)		5	23	17

Table 6. Doublegee (*Emex australis*), two trials, plants 4 and 8 weeks old, (1 to 3 and 3 to 4 leaf).

Treatment	Rate g a.i. ha^{-1}	Visual % control		Plants m^{-2} 40 DAA
		7 DAA	14 DAA	
glyphosate	270/360	10	79	6
+ carfentrazone	6	97	99	4
+ carfentrazone	12	99	99	2
+ carfentrazone	18	95	100	1
+ oxyfluorfen	18	67	90	5
+ oxyfluorfen	30	79	94	6
Untreated				18

The demonstrated effectiveness of carfentrazone-ethyl on species such as wild radish and doublegee provides another useful tool in the resistance management of these and other species, whilst at the same time providing excellent control levels for some of the more difficult broad leaved weed species.

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