Managing patches of glyphosate resistant *Echinochloa colona*: can they be eradicated?

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Summary Glyphosate-resistant *Echinochloa colona* L. (Link) is becoming common in non-irrigated cotton systems. *Echinochloa colona* is a small seeded species that is not wind-blown and has a relatively short seed bank life. These characteristics make it a potential candidate to attempt to eradicate resistant populations when they are detected.

A long term systems experiment was developed to determine the feasibility of attempting to eradicate glyphosate resistant populations in the field. To this point the established Best Management Practice (BMP) strategy of two non-glyphosate actions in crop and fallow have been sufficient to significantly reduce the numbers of plants emerging, and remaining at the end of the season. Additional eradication treatments showed slight improvement on the BMP strategy, however were not significant overall. The effects of additional eradication tactics are expected to be more noticeable as the seed bank gets driven down in subsequent seasons.

Keywords Glyphosate resistance, *Echinochloa colona*, eradication.

INTRODUCTION

Glyphosate-resistant *Echinochloa colona* (L.) Link is now widespread in grains systems, and is becoming increasingly common in non-irrigated cotton systems (Werth *et al.* 2013). *Echinochloa colona* is a small seeded, predominately self-pollinating species with a relatively short seed bank life (up to six years), and is not dispersed by wind. In the field, resistance generally appears as small patches that spread if not correctly managed. The population dynamics of *E. colona* make it a potential candidate for eradication if suspect patches are detected and managed early.

Previous simulations on glyphosate resistance management in summer grasses have indicated that a '2+2' approach (two non-glyphosate tactics in both crop and fallow) is effective for prevention and management of resistance (Thornby *et al.* 2013). This has now been adopted by the industry as a BMP approach to prevent/manage herbicide resistance in cotton systems. If resistant populations of *E. colona* are detected early enough, it may be possible to take measures to eradicate them with additional tactics in the short term, rather than allowing them to proliferate and become a long-term problem. Therefore, a systems experiment was established in order to determine what is required to eradicate patches of glyphosate-resistant *E. colona* in the field. The experiment examines the effect of the '2+2' approach on *E. colona* patches, and what additional tactics need to be applied and when they need to be applied in order to be effective. This research will provide growers with information as to whether it is not only possible, but also realistic to try to eradicate resistant patches of *E. colona*.

MATERIALS AND METHODS

The trial is located at Hermitage Research Facility near Warwick, Queensland. The site had an existing population of *E. colona*, these plants were allowed to remain for the first season in order to build up the population of barnyard grass before the experiment commenced in September 2012.

The experiment consists of nine treatments (Table 1). As the experiment assumes a glyphosate resistant *E. colona* population, all glyphosate treatments are applied at a low dose (170 g a.i. ha⁻¹) in order to allow 30–40% survivors. This level was designed to

Table 1. Overall treatments on the Hermitage patch eradication site. Treatments 2–9 contained an additional eradication tactic in each respective phase.

Treatment No.	Treatment
1	Glyphosate only (sub-lethal)
2	BMP
3	BMP + Eradication (phase 1)
4	BMP + Eradication (phase 2)
5	BMP + Eradication (phase 3)
6	BMP + Eradication (phase 1 and 2)
7	BMP + Eradication (phase 1 and 3)
8	BMP + Eradication (phase 2 and 3)
9	BMP + Eradication (phase 1, 2 and 3)

simulate when it is likely that glyphosate resistance could be identified in the field and mitigation/eradication measures taken.

Each season the experiment is broken up into three main phases: 1 – Early season (October – mid December). 2 – Mid season (mid December – mid February). 3 – Late season (mid February onwards). The eradication treatments consisted of an additional tactic applied in the phase/s as is listed in Table 1. In the first year of the experiment (glyphosate-resistant cotton), all treatments received five sub-lethal applications of glyphosate (one pre-plant, three early-mid season and one pre-harvest). The BMP treatments also received a paraquat + pedamethalin application post-plant-pre-emergent and a mid-season application of diruon. The eradication treatments received a metolachlor application pre-plant (phase 1), shielded paraquat (phase 2), and/or a hand hoeing at the end of the season (phase 3). Herbicides used and rates are listed in Table 2.

In the second year (fallow) all treatments received two sub-lethal glyphosate applications (phase 1 and 3). The BMP treatments received a metolachlor (phase 1) and two double knocks (glyphosate fb paraquat seven days later) (phase 1 and 3). The second year was very dry so the only eradication treatment needed was a hand hoeing in phase 2. The efficacy of the eradication control tactics is listed in Table 3.

Measurements Soil cores were taken at the start of the experiment, and after every season to determine changes to the seed bank in each treatment. Cores were taken with a hand corer 10 cm in diameter, with nine cores taken per plot. The starting seed bank ranged from 49,000 to 110,000 seeds m^{-2} (Figure 1). Differences in the starting seed bank were significant across treatments (P <0.05). Therefore subsequent analysis of effectiveness of treatments was taken with respect to the seed bank and emergence in each treatment, rather than across all treatments.

Table 2. Herbicides and rates used throughout the patch eradication experiment.

Active	Product	Rate (g a.i. ha^{-1})	Water rate (L ha^{-1})
Glyphosate	Roundup Powermax	170	85
Paraquat	Gramoxone	625	100
Metolachlor	Bouncer	1440	100
Pendamethalin	Stomp Xtra	1502	100
Duiron	Duiron 900DF	1800	100

Table 3. Efficacy of control measures used in each respective treatment.

Tactic	Treatment/s	Percent control
Year 1		
Metolachlor (pre-plant)	Eradication – phase 1 (Treatments 3,6,7 and 9)	65
Double knock (at-plant)	BMP (Treatments 2–9)	99
Pendamethalin (at-plant)	BMP (Treatments 2–9)	91
Double knock (in-crop)	Eradication – phase 2 (Treatments 4,6,8 and 9)	87
Diuron (layby)	BMP (Treatments 2–9)	83
Chipping	Eradication – phase 3 (Treatments 5,7,8 and 9)	73
Sub-lethal glyphosate (both years)	All treatments	74–96
Year 2		
Metolachlor	BMP (Treatments 2–9)	97
Double knocks	BMP (Treatments 2–9)	96–99
Hand-hoeing	Eradication – phase 2 (Treatments 4,6,8 and 9)	100

Plant counts were taken approximately one-two weeks after rainfall to measure emergences, and two-three weeks after post-emergent herbicide applications to measure survival rates. Counts were taken using quadrats (0.5 m × 1 m) up the center meter of the plot with five quadrats per plot.

RESULTS AND DISCUSSION

The total *E. colona* emergence for all treatments throughout the first season was quite high although this was expected to due the very high starting seed bank (Figure 1). However, the level of emergence in proportion to the starting seed bank was relatively low. Only 1.3% of the starting seed bank germinating throughout the season in the glyphosate only treatment that received no residual herbicides compared to the BMP treatment had 0.38% emergence. Treatments 3, 6, 7 and 9 with eradication measures in phase 1 had significantly less, ranging from 0.1–0.2% (P <0.001). This is a result of the pre-plant metolachlor having a significant effect on reducing emergence at the start of the season. The overall low emergence proportions are an indicator that the numbers of plants emerging can underestimate the size of the seed bank and the potential weed problem.

The glyphosate only treatment had the highest number of plants remaining at the end of season one (27.9 plants m^{-2}) compared to the next highest (9.7 plants m^{-2}) in the BMP + Erad (phase 1) treatment. However, when expressed as a percentage of total emergences in each treatment (Table 4), both the BMP + Erad (phase 1 and 2) had significantly higher proportions of plants remaining than the other treatments (P = 0.003). Reasons for this are unclear, but may be linked to a higher starting seed bank (Figure 1) and no additional eradication tactics in phase 3.

Emergence throughout the second season of the experiment was lower than the first (data not analysed). However they were slightly higher in proportion to the remaining seed bank from the first season. Emergence in the glyphosate only treatment was 3.3% and ranged from 0.3–0.5% for the other treatments (not all soil cores have been counted for the second season to date).

The application of an early season metolachlor had a significant impact on reducing emergence of the other treatments, compared to the glyphosate only treatment. The second season consisted of a long hot dry spell which negated the need for control measures that were expected to be applied. As a result there appeared to be no difference between the BMP and
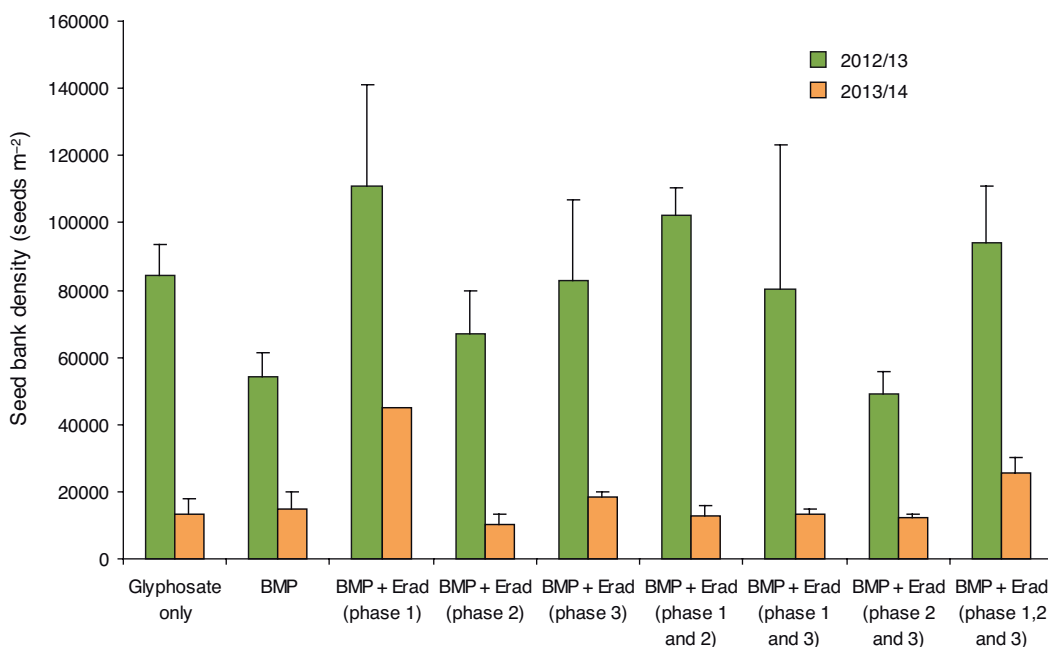
Figure 1. Seed bank density of *Echinochloa colona* at start of growing season for each treatment. Columns in 2013/14 without error bars have not had all replications counted to date.

Table 4. *Echinochloa colona* emergence and number of plants remaining with respect to each treatment in the first two years of the eradication experiment. Emergence is expressed as the percentage of the starting seed bank with respect to year and treatment. Plants remaining are expressed as the percentage of total emergence with respect to year and treatment. Means with the same subscript are not significantly different.

Treatment	Year 1 – Cotton		Year 2 – Fallow	
	Emergence (% starting seed bank)	Plants remaining (% emergence)	Emergence[A] (% starting seed bank)	Plants remaining[B] (% emergence)
Glyphosate only	1.34 a	2.34 a	3.34	9.26
BMP	0.38 bc	2.55 a	0.39	0.00
BMP + Erad (phase 1)	0.12 d	6.63 b	0.31	0.00
BMP + Erad (phase 2)	0.42 b	2.63 a	0.44	1.35
BMP + Erad (phase 3)	0.48 b	0.59 a	0.47	0.35
BMP + Erad (phase 1 and 2)	0.09 d	6.29 b	0.38	0.00
BMP + Erad (phase 1 and 3)	0.21 cd	2.21 a	0.40	0.30
BMP + Erad (phase 2 and 3)	0.40 bc	1.15 a	0.27	0.49
BMP + Erad (phase 1,2 and 3)	0.13 d	1.82 a	0.30	0.00
LSD (P <0.05)	0.20	2.89		
P-value	<0.001	0.003		

[A] Emergence was not analysed as not all seed from soil cores has been counted.
[B] Plants remaining was not analysed due to the presence of zero values.

BMP + Eradication treatments. The slight difference in plants remaining at the end of the season was only due to slight variability in the last double knock application.

All treatments considerably reduced the *E. colona* seed bank after the first season. Although not all replications of cores have been counted, there appear to be no differences in the size of the seed bank in relation to treatment. This is most likely due to the large starting point for seed bank numbers, and the impacts of each treatment are expected to be seen after a couple of seasons.

To this point in the experiment, both the BMP and BMP + Eradication treatments have reduced the level of emergence, and the numbers of plants remaining at the end of the season compared to the glyphosate only treatment. This shows that the '2+2' (two non-glyphosate tactics in crop and fallow) strategy is effective at managing populations of glyphosate-resistant *E. colona*. At this stage the extra benefits of eradication measures are only marginally apparent, however these are expected to be more significant throughout the course of the experiment.

REFERENCES
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