Prolonging glyphosate effectiveness on difficult to control summer weeds

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Summary Heavy reliance on glyphosate in conservation farming systems has resulted in the prevalence of certain weed species favoured by its over use. If the effectiveness of glyphosate on these weeds continues to decline, the sustainability of these systems will be impacted adversely. This study aims to determine effective ways to improve control of the problem weeds: fleabane, barnyard grass and sweet summer grass without increasing their glyphosate tolerance or resistance. The double knock tactic was investigated for its effectiveness in controlling these species and preventing seed-set. Results showed that following glyphosate and glyphosate mixes with either paraquat + diquat or paraquat provided highly effective control (up to 100%) of these species. Fleabane control was reduced as the interval for the follow-up application increased beyond 14 days. This study has shown that sequential knockdown treatments are effective in controlling glyphosate tolerant weeds, potentially preventing herbicide resistance evolution and thus prolonging the effectiveness of glyphosate.

Keywords Glyphosate, sweet summer grass, barnyard grass, flaxleaf fleabane, double knock.

INTRODUCTION

Glyphosate is an important herbicide in Australian agriculture due to its effectiveness on a broad spectrum of weeds, its low price, and its minimal impact on the environment (Baylis 2000). It has particular importance in management of weeds in conservation farming systems.

The widespread use of glyphosate in the fallows of the northern grains region has increased the risk of resistance evolution and has resulted in a shift towards weed species favoured by its use.

Sweet summer grass (*Brachiaria eruciformis* (Sm.) Griseb.) is a major weed of central Queensland and barnyard grass (*Echinochloa colona* (L.) Link) is widespread throughout the northern grains region. These small-seeded grass weeds have a high fecundity, emerge in high numbers and are exposed to glyphosate a number of times throughout spring and summer. These characteristics make them ideal candidates for glyphosate resistance evolution.

Flaxleaf fleabane (*Conyza bonariensis* (L.) Cronquist) is a small seeded broadleaf species that is tolerant to glyphosate (Walker and Robinson 2007). This characteristic has aided its widespread increase in the cropping areas of Queensland and northern New South Wales. It is particularly a problem on medium to light soils in no-till areas (Storrie 2007).

The use of sequential knockdown herbicide applications from different herbicide mode-of-action groups, known as the double knock tactic, has been used successfully in southern Australia for the management of glyphosate resistant ryegrass (Borger and Hashem 2007). This method has been developed so that survivors of the first herbicide application are controlled by the second to prevent seed production. Prevention of seed set is critical for resistance prevention and management. This practice has also been adopted by some growers to control fleabane where tillage is not considered an option.

The aim of these experiments is to better understand how the double knock tactic can be applied to problem weeds in the northern grains region.

MATERIALS AND METHODS

Herbicides and rates used for the respective experiments are listed in Tables 1 and 2.

Barnyard grass The trial was located at Dalby on the eastern Darling Downs. Weed counts were taken before and after treatment to assess control levels achieved. Glyphosate and paraquat were applied at water rates of 75 and 100 L ha^{-1} respectively with medium sized droplets. Paraquat double knock applications were applied seven days after glyphosate application. Seed set was measured on plants surviving herbicide application.

Sweet summer grass This trial was conducted at Emerald Research Station. Water rates for glyphosate and paraquat applications were 6 L and 100 L ha^{-1} respectively. Glyphosate was applied using coarse droplets and paraquat with medium droplets. Paraquat double knock applications were applied 13 days after glyphosate application. Percent control was assessed

by visual assessments. Seed production was measured on plants surviving herbicide application.

Fleabane This trial was conducted near Dalby. Weed counts were taken before and after treatment to assess percentage control. Glyphosate and 2,4-D were applied at water rates of 75 L ha^{-1}. Paraquat and diquat were applied at 100 L ha^{-1}. The effect of timing between application of the first and second knockdown herbicides was also examined.

RESULTS

Barnyard grass Glyphosate achieved up to 98% control at a low rate of 0.8 L ha^{-1} (Table 1). In the drought season in which this experiment ran, no seed was set in this treatment. However, in a typical summer season, summer rains would enable any survivors to set seed. Paraquat applied alone was not able to achieve 100% control and, at a rate of 1.2 L ha^{-1} (250 g a.i. L^{-1}), 27 seeds m^{-2} were set. Only the double knock treatments were able to achieve 100% control of barnyard grass, irrespective of the initial or follow-up herbicide rates (Table 1).

Sweet summer grass This species is susceptible to glyphosate, with over 95% control being achieved in all treatments, even at low rates of 0.5 L ha^{-1}. Paraquat also achieved high levels of control of this species, although no herbicides used alone were able to prevent seed set. When glyphosate applications were followed by paraquat 13 days later, good control including seed set prevention in some cases was achieved.

Fleabane This species' tolerance to glyphosate was evident in the poor level of control achieved when glyphosate was used alone (55%) (Table 2). When paraquat + diquat was added as the second knock, control improved considerably. However as the time between treatments increased, the level of control reduced slightly. The addition of 2,4-D provided 99–100% control in nearly all treatments containing glyphosate, and paraquat + diquat. Although seed production was not measured in this experiment, it is evident that 100% control will result in no seed production. In general, increased timing between the first and second applications decreased the level of control.

DISCUSSION

The effectiveness of the double knock tactic in controlling the key weeds, barnyard grass, sweet summer grass and fleabane has been clearly shown, particularly where robust herbicide rates have been used. There is a definite place for this tactic in the northern grains region of Australia, in order to improve weed management and prolong the effectiveness of glyphosate, particularly in conservation farming systems.

This tactic is also effective in reducing the risk of glyphosate resistance through stopping seed set. These species can produce large numbers of seed (Table 1) and a small number of escapes can result in a large problem in subsequent years. It is unlikely that growers will be able to use this tactic for all flushes each season every year.

However, simulations by Thornby *et al*. (2008) have shown that when applied to the largest flush each year, glyphosate resistance evolution in barnyardgrass can be prevented. Neve *et al*. (2003) have also shown that applying glyphosate and paraquat + diquat in 6 out of 10 years resulted in minimal resistance evolution in ryegrass over a 30 year period.

This makes the double knock tactic very important as a preventative measure against glyphosate resistance. Moreover, should glyphosate resistance evolve in these species, the double knock tactic will have an important role in resistance mitigation.

Table 1. Control achieved on summer grasses with the double knock tactic (glyphosate followed by paraquat is denoted by 'gly, para').[A]

Herbicide	Rate (L ha^{-1})	Control (%)	Seed set (no. m^{-2})
Barnyard grass			
nil		0	3,292
glyphosate	0.8	98	0
glyphosate	1.6	100	0
paraquat	1.2	97	27
paraquat	2.0	99	0
gly, para	0.8, 1.2	100	0
gly, para	0.8, 2.0	100	0
gly, para	1.6, 1.2	100	0
gly, para	1.6, 2.0	100	0
Sweet summer grass			
nil		0	243,832
glyphosate	0.5	99.3	32
glyphosate	1.0	97.7	25
paraquat	1.0	99.3	109
paraquat	1.5	98	485
paraquat	2.0	98.7	253
gly, para	0.5, 1.0	98.7	4
gly, para	1.0, 1.0	100	0
gly, para	0.5, 1.5	97.7	18
gly, para	1.0, 1.5	100	0
gly, para	0.5, 2.0	99.3	0
gly, para	1.0, 2.0	100	0

[A]Herbicide formulations: glyphosate 450 g a.e. L^{-1}; paraquat 250 g a.i. L^{-1}.

Table 2. Control achieved on fleabane with the double knock tactic in the field.[A]

First knock	Second knock	Days after first knock	Control (%)
glyphosate 2 L ha^{-1}			55
glyphosate 2 L ha^{-1}	paraquat + diquat 1.6 L ha^{-1}	7	96
glyphosate 2 L ha^{-1}	paraquat + diquat 1.6 L ha^{-1}	14	96
glyphosate 2 L ha^{-1}	paraquat + diquat 1.6 L ha^{-1}	21	88
glyphosate 2 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	7	97
glyphosate 2 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	14	88
glyphosate 2 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	21	94
glyphosate 2 L ha^{-1} + 2,4-D 1.5 L ha^{-1}	paraquat + diquat 1.6 L ha^{-1}	7	98
glyphosate 2 L ha^{-1} + 2,4-D 1.5 L ha^{-1}	paraquat + diquat 1.6 L ha^{-1}	14	100
glyphosate 2 L ha^{-1} + 2,4-D 1.5 L ha^{-1}	paraquat + diquat 1.6 L ha^{-1}	21	95
glyphosate 2 L ha^{-1} + 2,4-D 1.5 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	7	99
glyphosate 2 L ha^{-1} + 2,4-D 1.5 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	14	99
glyphosate 2 L ha^{-1} + 2,4-D 1.5 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	21	99
glyphosate 2 L ha^{-1} + 2,4-D 3 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	7	100
glyphosate 2 L ha^{-1} + 2,4-D 3 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	14	99
glyphosate 2 L ha^{-1} + 2,4-D 3 L ha^{-1}	paraquat + diquat 2.4 L ha^{-1}	21	99

[A]Herbicide formulations: glyphosate, 450g a.e. L^{-1}; 2,4-D, 300 g a.i. L^{-1}; paraquat + diquat, 135 g a.i. paraquat L^{-1} + 115 g a.i. diquat L^{-1}.

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