A new glyphosate resistant weed species confirmed for northern New South Wales and the world: common sowthistle (*Sonchus oleraceus*)

Tony Cook, Bill Davidson and Rebecca Miller
Department of Primary Industries, Tamworth Agricultural Institute, 4 Marsden Park Road, Calala, NSW 2340, Australia
(tony.cook@dpi.nsw.gov.au)

Summary Two populations of common sowthistle (*Sonchus oleraceus* L.) were reported to survive straight applications of glyphosate in northern New South Wales. These were subsequently proven to be glyphosate resistant following applications of glyphosate at 720 g a.i. ha^{-1}. This news represents the first reporting and confirmation of a glyphosate resistant *Sonchus* species internationally. It is now the seventh recognised glyphosate resistant weed in Australia.

Growth stage of common sowthistle at the time of treatment had a noticeable effect on the survival rates. The disparity in control between resistant and susceptible populations was more pronounced once common sowthistle surpassed the early stem elongation stage. In essence, it appears that control of glyphosate resistant common sowthistle may be feasible if treated at the early rosette stage, even with glyphosate. This interaction between growth stage and glyphosate resistance status is common amongst other glyphosate resistant weed species (Cook 2008).

These findings have serious implications for grain and cotton producers in the northern region and for those that manage non-crop areas, such a roadsides and railway corridors. These areas have often relied heavily upon glyphosate as their herbicide of choice. The alternative options may not be as effective and as robust as glyphosate.

Keywords Glyphosate, resistance, sowthistle, *Sonchus oleraceus*.

INTRODUCTION

Common sowthistle (*Sonchus oleraceus* L.) is an annual broad-leaf weed of grain, cotton crops and non-crops areas in northern New South Wales and Queensland (Walker *et al*. 2005, Osten *et al*. 2007). Widderick *et al.* (2004) reported that common sowthistle germinates predominantly from the top 1 cm of soil. The same study noted that seed can germinate within a temperature range of 5 to 35°C. Therefore, its abundance in these areas is primarily due to reduced tillage farming systems that allow the surface germinating seed to establish. This weed can occur all year round due to its ability to germinate in temperatures that are common throughout the year.

The weed has a large seed production potential. Plants grown in glasshouse conditions were capable of producing 8000 seeds per plant whereas those growing in fallow field conditions could produce up to 86,340 seeds m^{-2} (Widderick *et al.* 2004).

Common sowthistle developed resistance to ALS inhibitor herbicides following the repeated use of chlorsulfuron in southern Queensland and northern New South Wales (Adkins *et al.* 1997). Furthermore, a survey by Walker *et al.* (2004) acknowledged this weed as having a moderate risk of developing resistance to EPSP synthase herbicides (glyphosate), as this herbicide is regularly used to control this weed. The international herbicide resistant weed survey has no reports of any *Sonchus* species as glyphosate resistant (Heap 2014).

This paper outlines results from two experiments that investigated the response of two common sowthistle populations suspected of having glyphosate resistance.

MATERIALS AND METHODS

Two glasshouse experiments were initiated at the Tamworth Agricultural Institute. The first experiment investigated responses of three common sowthistle biotypes to label and sub-label rates of glyphosate. Two of these biotypes suspected of having glyphosate resistance were sourced from the Liverpool Plains district of northern NSW. For the purpose of this report they are referred to as 'Yellow' and 'CRK' biotypes. A herbicide susceptible standard was included, referred to as 'White' biotype. These three biotypes were also used in the second experiment that investigated sub-label, label and higher than label rates of glyphosate, applied at three growth stages. The standard registered label rate of glyphosate is 720 g a.i. ha^{-1}; however, broad label claims have rates between 270 and 1000 g a.i. ha^{-1}, depending on weed growth stage or type of product.

Plants were grown for the majority of the time inside the glasshouse but were 'hardened up' by moving them outside for a period of seven days prior to spraying to simulate plants grown under field conditions. Due to the slow response of glyphosate on this species, the last assessment of herbicide efficacy was made 56 days after treatment (DAT).

Other relevant experimental details are described in Table 1.

RESULTS

Experiment 1 Green biomass of large rosette common sowthistle declined when glyphosate rates increased from 0 to 720 g a.i. ha^{-1} (Figure 1). No improvements to common sowthistle control occurred when glyphosate rates increased from 720 to 1000 g a.i. ha^{-1}. Green biomass of the 'White' biotype was significantly lower ($P < 0.05$) compared to the other biotypes at 360, 720 and 1000 g a.i. ha^{-1}.

The 'Yellow' biotype had more biomass compared to the 'CRK' populations after glyphosate was applied at 360 and 720 g a.i. ha^{-1}. At the commercial standard rate (720 g a.i. ha^{-1}), the susceptible standard population ('White') resulted in commercial control (≥80% control) or no green biomass. The percent control of the 'Yellow' and 'CRK' biotypes at this rate were 69 and 78% respectively. Regeneration of these biotypes was apparent and plants with green biomass were likely to survive and set seed.

The glyphosate dose responses of early flowering common sowthistle are shown in Figure 2. Consistently lower biomass was measured for the 'White' biotype across the three higher rates of glyphosate, compared to other biotypes.

Total biomass of the 'Yellow' biotype was least affected after the 720 g a.i. ha^{-1} rate of glyphosate. Biomass was reduced from 72 to 56 g of green biomass per plant, or 22% control. However, the 'White' biotype was reduced from 56 to 5 g per plant, a reduction of 91%. The reduction in biomass for the 'CRK' population was 63% for the same rate of glyphosate.

Comparing the responses of large rosette plants to those at the early flowering stage, there is a trend

Table 1. Experimental details for glyphosate resistance testing of common sowthistle.

	Experiment 1	Experiment 2
Glyphosate rates g a.i. ha^{-1}	0, 360, 720 and 1000	0, 360, 720, 1260 and 1800
Growth stages treated	Stage 1: 20 cm diam. rosettes; and Stage 2: bolting/early flowering	Stage 1: 10 cm diam. rosettes; Stage 2: early bolting; and Stage 3: mid flowering
Plants per pot	1	1
Replicates per treatment	5	5
Spray dates	Growth stage 1: 1/11/2013 Growth stage 2: 22/11/2013	Growth stage 1: 9/1/2014 Growth stage 2: 29/1/2014 Growth stage 3: 11/3/2014

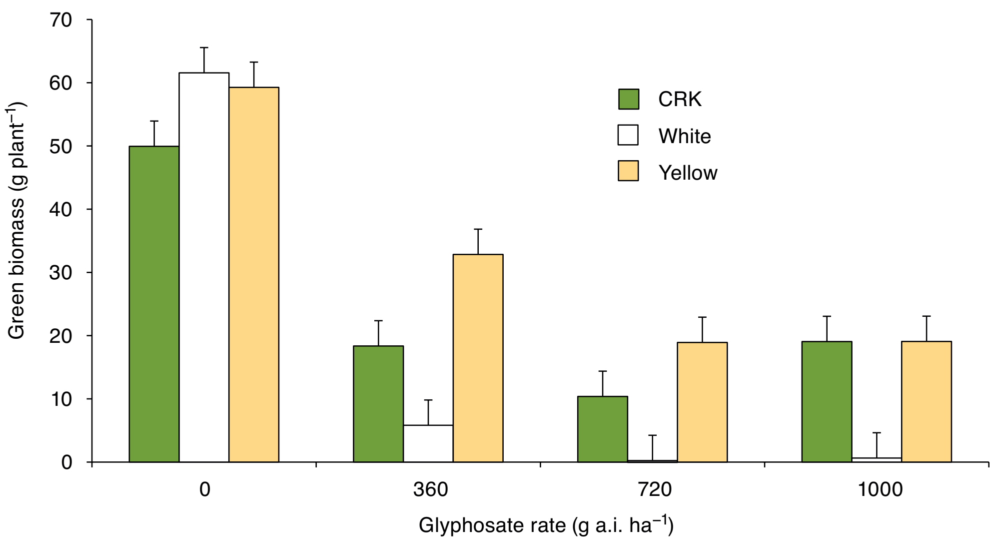

Figure 1. Effect of glyphosate rates on the green biomass of three different common sowthistle biotypes measured 56 DAT. Treatments applied to large rosette plants (standard error bars shown).

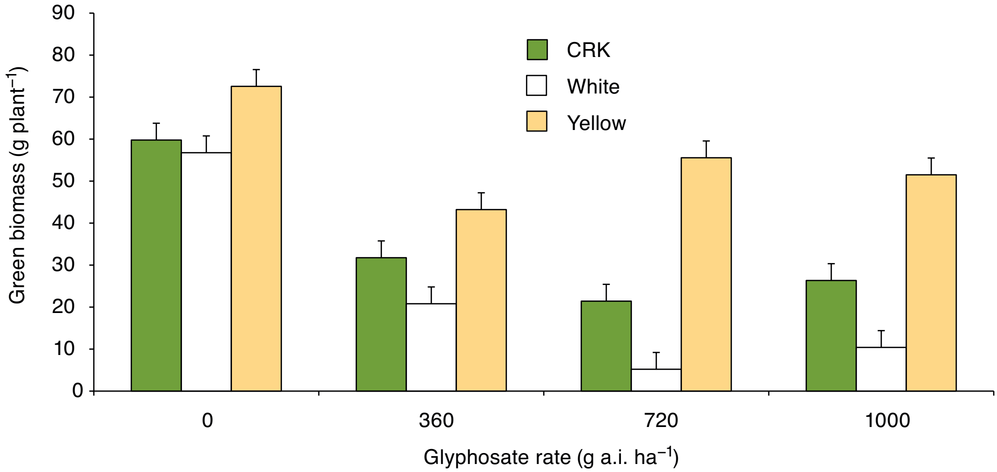

Figure 2. Effect of glyphosate rates on the green biomass of three different common sowthistle biotypes measured 56 DAT. Treatments applied to bolting/early flowering plants (standard error bars shown).

of increasing biomass production for plants treated at the more advanced growth stage. Notably, commercial control was still maintained at the standard glyphosate rate on the 'White' biotype.

Common sowthistle flower buds per plant were 33 and 23 for the 'Yellow' and 'CRK' populations respectively, significantly ($P < 0.05$) more than no flower buds measured for the 'White' biotype, after treating with 720 g a.i. ha^{-1} of glyphosate (data not presented).

Experiment 2 Robust rates of glyphosate (720 to 1800 g a.i. ha^{-1}) controlled common sowthistle regardless of biotype, if applied to the smaller 10 cm diameter rosette stage (Table 2). The standard label rate of glyphosate (720 g a.i. ha^{-1}) resulted in commercial control (≥80% control) of all biotypes at the early growth stage, but failed to control the 'Yellow' and 'CRK' populations beyond that stage. Control of the susceptible standard was marginally acceptable at stem elongation stage (GS 2) and was inadequate at the mid flowering stage (GS 3).

Lower levels of control were reported for the 'Yellow' population compared to the 'CRK' biotype at GS 2 and 3 for glyphosate rates of 720, 1260 and 1800 g a.i. ha^{-1}. This higher level of survival from the 'Yellow' biotype was also observed in experiment 1.

Table 2. Common sowthistle control (% biomass control), relative to nil herbicide rate, following various glyphosate rates and the effect of three growth stages 56 DAT.

	Growth stage		
Glyphostae (g a.i. ha^{-1})	GS 1	GS 2	GS 3
'White' biotype			
360	79	76	−35
720	100	81	33
1260	100	100	100
1800	100	100	100
'Yellow' biotype			
360	55	27	−15
720	97	−13	−87
1260	95	16	−16
1800	97	63	4
'CRK' biotype			
360	64	7	−8
720	80	35	5
1260	91	71	58
1800	97	78	100

Note: negative values indicate an increase in common sowthistle biomass compared to the nil herbicide rate. Data was not analysed due to harvesting of plants just prior to paper preparation.

DISCUSSION

These results were presented to the Australian Glyphosate Sustainability Working Group (AGSWG) in early 2014. The committee deemed that the 'Yellow' and 'CRK' populations to be glyphosate resistant. Rationale behind this decision was the significantly higher survival rates at the standard label rate compared to a susceptible population. This was further highlighted at the higher glyphosate rates. In addition, expression of glyphosate resistance is more apparent once plants develop beyond the small rosette stage and the plants commence bolting or stem elongation.

Discovery of two glyphosate resistant populations of common sowthistle raises concern for farmers in the northern grain region and beyond. These populations originally found in Liverpool Plains district of northern New South Wales now have the capacity to spread by wind borne seed to other districts. Surveys are presently underway to gauge the spread of resistance in the northern grain region. In time, southern regions should be surveyed to determine the extent of resistance to glyphosate.

The highest glyphosate rates used in experiment 2 were included as a comparison with the highest fallow rate allowed by a Pesticide Permit 11163. This national Permit allows glyphosate at 1800 g a.i. ha^{-1} in fallow situations via the use of WeedSeeker® technology. It appears this high rate will not be ample to control well-developed glyphosate resistant biotypes. Also the discovery of glyphosate resistant common sowthistle may compromise the value of glyphosate tolerant crops grown in the region. Rates of glyphosate used in these crops are 621 and 1035 g a.i. ha^{-1} for canola and cotton respectively.

With the confirmation of glyphosate and ALS inhibitor resistance in different populations of common sowthistle, there will be more selection pressure on synthetic auxin chemistry. Further to this point, herbicide mode-of-action Groups C, G, H and L could be used more to take resistance selection pressure off Groups B, I and M.

Necrosis of foliage following glyphosate application is very slow. More time is needed to complete glyphosate resistance testing of common sowthistle compared to other species such as *Echinchloa colona* (L.) Link (awnless barnyard grass) and *Lolium rigidum* Gaudin (annual ryegrass) (Boutsalis 2001). At least 56 days is required to determine difference between treatments. The preferred growth stage to treat common sowthistle is the stem elongating (bolting) to early flowering stage when testing for resistance. However, to obtain commercially acceptable results it is best to treat small rosette common sowthistle (<10 cm diameter) if using glyphosate. Alternative modes-of-action herbicides are preferred and many of these alternatives provide excellent control of this weed.

The susceptible standard or ‘White’ biotype, collected around Tamworth, did not completely die on some occasions; however control of biomass was very high. The history of these plants is hard to determine as they could have blown in from an area that had a reasonable glyphosate history. The search for a more appropriate susceptible standard has found a population more susceptible than that used in this study. It will be used in future herbicide resistance testing as the preferred susceptible standard.

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