Recruitment and fecundity of annual ryegrass, great brome grass, barley grass, doublegee and sowthistle

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Summary An experiment was conducted at Wongan Hills Western Australia (WA) in 2016 and 2017, to investigate the biology of ten weed species. The trial investigated recruitment, germination time, survival over the cropping season, seed production and time of shedding. This paper reports the results of annual ryegrass (*Lolium rigidum* Gaudin), great brome grass (*Bromus diandrus* Roth), barley grass (*Hordeum leporinum* Link), doublegee (*Rumex hypogaeus* T.M.Schust. & Reveal, formerly *Emex australis* Steinh) and sowthistle (*Sonchus oleraceus* L.).

Great brome grass seedling recruitment was higher than annual ryegrass recruitment in 2017, even though annual ryegrass had much higher seed set in 2016. Further, brome grass had the greatest impact on crop yield in 2017. Brome grass, barley grass, doublegee and sowthistle all shed their seed earlier than annual ryegrass. Harvesting as early as possible or swathing would be necessary to capture seeds from these species for harvest weed seed destruction.

Keywords *Lolium rigidum*, *Bromus diandrus*, *Hordeum leporinum*, *Rumex hypogaeus*, *Emex australis*, *Sonchus oleraceus*, germination, seed production, shedding.

INTRODUCTION

Annual ryegrass is the worst cropping weed in Australia in terms of area infested, impact on crop yield and cost of herbicide resistance management (Llewellyn *et al*. 2016). However, changes to the agronomic system and environment have ensured that other winter weed species are increasingly detrimental. For example, brome grass species are now the fourth most problematic weed in Australia (Llewellyn *et al*. 2016). A trial at Wongan Hills, Western Australia (WA) aimed to investigate the biology of eleven weed species, including Afghan melon, annual ryegrass, barley grass, button grass, caltrop, doublegee, great brome grass, roly poly, sowthistle, windmill grass and wireweed. In this paper we compare the emergence, survival, seed production and shedding time of annual ryegrass, great brome grass, barley grass, doublegee and sowthistle growing in a wheat crop.

MATERIALS AND METHODS

An experiment was conducted at the Department of Primary Industries and Regional Development (DPIRD) Wongan Hills Research Station in 2016 and 2017 on yellow sand. In 2016, a site with few weeds was selected and prior to the trial, existing weeds were cleared using non-selective herbicide and cultivation (Table 1). Prior to seeding wheat cv. Mace, plots were sown with one of 11 different weed species; Afghan melon, annual ryegrass, barley grass, great brome grass, button grass, caltrop, doublegee, roly poly, sowthistle, windmill grass and wireweed. Seeds of each weed species were harvested from elsewhere on the Research Station or in the surrounding district in the prior year. The trial also included weed free control plots. The trial was established as a randomised block design with two dimensional balance (i.e. 12 weed species comparisons and 3 replications were blocked in two directions, Coombes 2008).

No in-crop herbicides were applied during the 2016 growing season. Any additional weed species in the trial were removed by hand and other pests were controlled as required. In 2017, the trial was resown to wheat cv. Mace. While a non-selective herbicide was applied, low summer and autumn rainfall at the site ensured that winter weeds did not germinate prior to seeding the crop. Again, non-target weeds were removed by hand and other crop pests were controlled where necessary.

Harvest was conducted at a height of 15 cm, and all chaff was spread back on the plot. Therefore, those weed seeds captured in the grain sample were removed from the plot but any weed seeds in the chaff were retained.

Each year, ten weeds per plot were marked with pegs (after seeding) to monitor growth and seed production of individual plants in the initial weed cohort. For all weed species, later cohorts emerged during the season, but the ten marked plants were the earliest weeds to appear in each plot as these early weeds were the largest/most competitive in crop. The seed heads of the marked weeds were bagged and checked every two weeks to monitor total seed production and time of shedding. Height of each seed head was also measured.

Weed density was assessed at multiple times during the season (time of assessment varied between weed species) from 50 cm by 50 cm quadrats. Weed density and seed production per plant were used to estimate weed seed production m^{-2}. This paper will discuss growth of the winter weeds; great brome grass, barley grass, annual ryegrass, doublegee and sowthistle.

RESULTS

Emergence and fecundity Emergence from the initial 100 seeds m^{-2} in 2016 ranged from 50 plants m^{-2} for sowthistle to 68 m^{-2} for barley grass (Table 2). Seed production was greatest in annual ryegrass, followed by great brome grass. However, plant density in 2017 was greatest for great brome grass, followed by annual ryegrass. These two species had increased seed production in 2017 compared to 2016. Barley grass, sowthistle and doublegee had reduced plant density in 2017 compared to 2016.

In each year, the first cohort of great brome grass and annual ryegrass (i.e. the marked plants in each plot) emerged at the same time as the crop and these marked plants remained at a similar growth stage to the crop throughout the year (data not presented). The marked plants in each plot had high survival rates during the growing season, with 97% survival of great brome grass and 100% survival of annual ryegrass until senescence prior to crop harvest. By comparison, the barley grass, doublegee and sowthistle all had the initial cohort germinate after the crop was established. The initial 10 barley grass plants per plot emerged from June to September and many plants died prior to seed set. All barley grass had naturally senesced by crop harvest, but some of the doublegee and sowthistle plants were still green in November 2016 and 2017.

Weed seed shedding In 2016 and 2017, the earliest possible harvest date occurred in mid-November (14/11/2016 and 9/11/2017, Table 3). In each year annual ryegrass shed 24% and 13% of seed prior to harvest in 2016 and 2017. All annual ryegrass seed heads were above harvest height. Compared to annual ryegrass, great brome grass seed shed rapidly over November. In mid-November (14/11/2016 and 15/11/2017), great brome grass had shed 64% of seed in 2016 and 70% of seed in 2017. Harvest in 2016 did not occur until December and 100% of seed was shed prior to harvest. In 2017 the crop was ready for harvest in November (9/11/2017) when great brome grass had only shed 28% of seed. All great brome grass seed heads formed above harvest height.

Barley grass started shedding seed in October, but retained 62% of seed at crop maturity in 2016 and 96% in 2017 (Table 3). However, in this particular trial, the barley grass was poorly competitive due to late emergence and the plants did not grow taller than 10–12 cm. Shedding was delayed because the seed heads on the short plants were protected from wind by

Table 1. Agronomic details for each operation involved in the experiment in 2016 and 2017.

Date	Operation
8/2/2016	Non-selective herbicide: glyphosate 810 g ai ha^{-1} (Roundup PowerMAX®) + 2,4-D ester 330 g ae ha^{-1} + triclopyr 36 g ai ha^{-1} (Garlon®).
7/4/2016	Cultivation: to 5 cm (autumn tickle to stimulate germination and emergence).
14/4/2016	Non-selective herbicide: glyphosate 1080 g ai ha^{-1} + carfentrazone-ethyl 6 g ai ha^{-1} (Hammer®).
9/5/2016	Cultivation: to 5 cm to kill remaining weeds.
26/5/2016	Sow weeds: manually spread 100 seeds m^{-2} of Afghan melon, annual ryegrass, barley grass, great brome grass, button grass, caltrop, doublegee, roly poly, sowthistle, windmill grass or wireweed over each plot. A weed free control treatment was also included.
26/5/2016	Seeding: Wheat cv. Mace (knife points with press wheels), at 80 kg ha^{-1}, 22 cm crop row spacing, 3–4 cm depth. MacroPro Plus® at 80 kg ha^{-1}, approximately 3 cm below the seed.
16/8/2016	Pest control: prothioconazole/tebuconazole 31.5/31.5 g ai ha^{-1} (Prosaro®) + alpha-cypermethrin 25 g ai ha^{-1} (Alpha-Scud®) + 1% wetter
1/12/2016	Harvest: at a height of 15 cm.
25/5/2017	Non-selective herbicide: paraquat/diquat 337.5/287.5 g ai ha^{-1} (Spray.Seed®).
25/5/2017	Seeding: The crop was sown as for 2016. No additional weed seeds were sown.
17/7/2017	Fertiliser: 50 L ha^{-1} Flexi-N®
12/9/2017	Pest control: dimethoate 160 g ai ha^{-1} (Dimethoate®)
23/11/2017	Harvest: at a height of 15 cm.

the crop. All seed heads were below the harvest height of 15 cm. As the barley grass plants had senesced, crop harvest caused sufficient disturbance to shed the remaining seed heads, and seeds were not captured by the harvester.

Sowthistle and doublegee plants started shedding seed in October, in both years. Sowthistle shed 94–95% of seed and doublegee shed 100% of seed prior to harvest in 2016 and 2017.

Note that the heavy spring rainfall in 2017 allowed many doublegee to remain green and continue growing throughout harvest and set seed during summer (Bureau of Meteorology 2017). Table 3 only includes doublegee seed from those plants that had senesced at harvest. Most sowthistle plants were below harvest height, with less than 1% of the marked plants taller than 15 cm in 2016 and 2017. All doublegee plants were below harvest height.

Crop yield In 2016, weed density was low and none of the weed species had a significant impact on crop yield (Table 2, Table 4). In 2017, the great brome grass plots had lower yield than the plots with other weed species ($P<0.001$, LSD: 407.6).

Table 4. Average yield of wheat in each year.

Species	2016 yield (kg ha^{-1})	2017 yield (kg ha^{-1})
Annual ryegrass	3961	1867
Great brome grass	3933	1251
Barley grass	4690	2062
Doublegee	5121	2230
Sowthistle	3856	2297
Weed free control	4008	1934

Table 2. Average density and seed production (m^{-2}) of each weed species in the 2016 and 2017 growing season. *Note that 2017 seed production is not available for doublegee as the plants remained green over summer and so assessment of seed production was delayed.

	2016		2017	
Species	Plant density	Seed production	Plant density	Seed production
Annual ryegrass	65	9366	203	29496
Great brome grass	60	3484	349	29129
Barley grass	68	889	42	884
Doublegee	55	336	7	*
Sowthistle	50	3207	8	2009

Table 3. The cumulative percent of seed shed by each weed species from October in each year. In 2016, the crop was harvested on 1/12/2016 but was ready for harvest on 14/11/2016. In 2017, the crop was harvested on 23/11/2017 but was ready for harvest on 9/11/2017. All species had 100% shedding at harvest as the harvester either caught seeds or caused sufficient disturbance that the seeds fell to the ground.

Species	7/10/2016	24/10/2016	7/11/2016	14/11/2016	25/11/2016	1/12/2016
Annual ryegrass	0	1	3	9	24	100
Great brome grass	0	0	1	64	100	
Barley grass	0	8	13	38	100	
Doublegee	0	63	82	82	100	
Sowthistle	0	27	32	87	95	100
Species	**9/10/2017**	**24/10/2017**	**9/11/2017**	**15/11/2017**	**23/11/2017**	
Annual ryegrass	0	1	3	13	100	
Great brome grass	0	6	28	70	100	
Barley grass	0	4	4	8	100	
Doublegee	25	25	100			
Sowthistle	0	0	72	94	100	

DISCUSSION

Great brome grass did not produce as many seeds as annual ryegrass in 2016, but still had higher seedling recruitment in 2017. Annual ryegrass seeds are small, with a very thin seed coat. Spafford Jacob *et al.* (2006) found that seed predation (by ants, mice etc.) of small seeds such as annual ryegrass can be close to 100% over summer in WA, whereas larger seeds like wild oats are a less desirable food source. Seed predation is the most likely reason for the low recruitment of small seeded species like annual ryegrass compared to large seeded species like great brome grass in the 2017 season. The great brome grass used in the current trial germinated at the same time as the crop, and was highly competitive with wheat, as indicated by the reduced crop yield in 2017. Therefore, it is very important to control great brome grass through an integrated weed management program (Storrie 2014). Harvest weed seed destruction may be an effective control measure for great brome grass. Walsh and Powles (2014) noted great brome grass seed retention of 77% at crop maturity, and Hashem *et al.* (2017) found 74% of great brome grass seed could be captured if harvest height was 10 cm. This is similar to the 72% seed retention at crop maturity in 2017 and much higher than the 36% retention in 2016 in the current study. It is clear that great brome grass seed retention at harvest varies between years due to seasonal conditions and the time at which the crop reaches maturity. Lodging of brome grass seed heads may also occur in some locations or seasons, which would influence the success of harvest weed seed destruction. For successful harvest weed seed destruction, harvest should be completed as soon as possible in those fields where great brome grass is a problem. Alternatively, swathing may be used to reduce weed seed shedding. Further research is required to determine the success of swathing or harvest weed seed destruction for great brome grass.

The barley grass used in this trial had delayed emergence, which has also been observed in barley grass in South Australia (Gill and Fleet 2012). Late emergence allows the seedlings to avoid non-selective herbicides, but would reduce their ability to compete with the crop (Gill and Fleet 2012). Barley grass retained seed more effectively than great brome grass, but plants in the current study were very short and so were protected from the wind. This would reduce shedding. Other populations may have earlier shedding and further research is required to determine if harvest weed seed destruction is effective for barley grass.

Doublegee and sowthistle also germinated well after the crop and were not highly competitive in this trial. These species are unlikely to be highly competitive in wheat crops, although further research is required in other locations and crop species. Prior research has indicated that doublegee can grow up into the crop canopy, particularly in short pulse crops, and can contaminate yield in some locations (Peltzer and Douglas 2017). Sowthistle tends to be more common in the southern wheatbelt and may be more competitive in this region than in Wongan Hills (Borger *et al.* 2018).

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