Evaluation of harvest weed seed control systems

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Summary Harvest weed seed control (HWSC) systems have been developed to exploit the high proportions of seed retained at maturity by dominant annual weeds of Australian cropping annual ryegrass (*Lolium rigidum*), wild radish (*Raphanus raphanistrum*), brome grass (*Bromus* spp.), and wild oats (*Avena* spp.). To evaluate the efficacy of HWSC systems on annual ryegrass populations, three systems, the Harrington Seed Destructor (HSD), chaff carts and narrow windrow burning were compared at 25 sites across the western and southern wheat production regions of Australia. Annual ryegrass counts in autumn were used to assess the impact of the previous harvest treatments on annual ryegrass populations. Low–moderate plant densities (1–26 plants m^{-2}) present at harvest produced high levels of seed production highlighting the need for targeting weed seed production. Autumn annual ryegrass counts identified that HWSC treatments were consistent in reducing annual ryegrass populations at each of the sites. On average, population densities were reduced by 56%, but there was considerable variation between sites (29–90%). As seen here, the use of chaff carts, narrow windrow burning or HSD HWSC systems act similarly on annual ryegrass seed collected during harvest to deliver substantial reductions in subsequent annual ryegrass populations by restricting seed bank inputs.

Keywords Non-chemical weed control, weed seed production.

INTRODUCTION

Seed retention at maturity has been identified as a key biological attribute (weakness) of the problematic annual weed species infesting Australian cropping. Annual ryegrass, wild radish, brome grass, and wild oats all retain significant proportions of total seed production at crop maturity (Walsh and Powles 2007). During grain harvest these seed are collected, processed and are then expelled from the harvester, predominantly in the chaff fraction. Ironically this harvest process results in the collected weed seeds being evenly redistributed/reseeded across the crop field (Barroso *et al.* 2006, Blanco-Moreno *et al.* 2004). Restricting seed bank inputs has been a focus for annual weed control for many years in Australian cropping and the harvest process was recognised in the 1980s as a weed control opportunity (Gill 1996, Matthews *et al.* 1996). Subsequently, a number of HWSC systems have been developed for the specific purpose of targeting weed seed during crop harvest to restrict contributions to the seed bank (Walsh *et al.* 2012, Walsh and Newman 2007, Walsh *et al.* 2013). There are a number of approaches that these systems use to target the weed seed bearing chaff fraction: collection and subsequent burning (chaff cart), concentration in a narrow windrow with straw residues for subsequent burning (narrow windrow burning), collected in bales along with straw residues (Bale Direct System) and mechanical destruction during harvest (HSD). The aim of this study was to establish the efficacy of three weed seed control systems, the HSD chaff carts and narrow windrow burning. The effect of these systems on annual ryegrass populations was compared across a range of western and southern wheat belt production environments.

MATERIALS AND METHODS

To evaluate HWSC systems across a range of crop production environments, a HSD and accompanying commercial harvester were used to establish trial sites across the western and southern wheat belt regions during the 2010 and 2011 harvests, respectively. In 2010 commencing in the northern WA wheat-belt in early November 2010, a 9650 John Deere harvester with attached HSD travelled south and east through the wheat-belt over a six week period establishing trial sites at 11 locations. In 2011 this equipment was used to establish 14 trial sites commencing on the Eyre Peninsula in November then travelling east and north through the SA, Vic and NSW wheat belt regions. At each location the HSD and harvester were used to establish control (no HWSC), narrow windrow burning and HSD treatments. Chaff cart treatments were established with local farmer equipment, where available. Treatments were established under commercial harvest conditions in wheat crops where

Table 1. Annual ryegrass plant density and seed production above harvester cutting height (15 cm) in wheat crops immediately prior to harvest in 2010 (WA) and 2011 (SA, Vic. and NSW). Numbers in parentheses represent standard errors around the means of four replicates.

	Annual ryegrass		
Location	Plants m^{-2}	Seed m^{-2}	Seed $plant^{-1}$
Binnu, WA	21 (5)	4410	210
Tenindewa, WA	16 (3)	2000	125
Mingenew, WA	26 (4)	4524	174
Buntine, WA	23 (3)	3680	160
Wongan Hills, WA	8 (2)	1792	224
Wyalkatchem, WA	15 (3)	2175	145
Corrigin, WA	4 (2)	1216	304
Kondinin, WA	26 (3)	4576	176
Holt Rock, WA	14 (3)	5320	380
Kojonuop, WA	6 (2)	2520	420
Broomehill, WA	8 (2)	1792	224
Minnipa, SA	3 (1)	522	174
Minnipa, SA	6 (1)	1675	279
Cummins, SA	5 (1)	1039	208
Bute, SA	5 (2)	591	118
Arthurton, SA	1 (1)	28	28
Pinnaroo, SA	6 (2)	356	59
Underbool, Vic.	1 (1)	59	59
Dimboola, Vic.	2 (1)	138	69
Dookie, Vic.	15 (3)	2509	167
Rand, NSW	5 (1)	2127	425
Old Junee, NSW	1 (1)	286	286
Harden, NSW	11 (2)	4017	365
Peak Hill, NSW	8 (1)	2879	360
Coonamble, NSW	10 (1)	796	80
Average	10 (2)	2041	209

moderate levels of annual ryegrass (1–25 plants m^{-2}) were present (Table 1).

Prior to harvest annual ryegrass plants were counted and seed heads above harvester cutting height (15 cm) were collected from 10 × 1.0 m^2 quadrats across the trial site. Seed heads were subsequently threshed and the collected seed counted. Treatments were established in 11 m × 50 m strips in a randomised block design with four replicates.

The following autumn after the season opening rains annual ryegrass emergence was recorded on each plot across all sites to assess HWSC treatment effects. At each site annual ryegrass plant densities were determined in each plot by counting annual ryegrass in 20 × 0.1 m^2 quadrats. An analysis of variance, using SAS statistical software (SAS Institute Inc., Cary, NC 27513, USA) was performed on annual ryegrass plant counts and plant density reductions. Due to site differences ($P < 0.05$), data analyses comparing HWSC treatments were performed for each location.

RESULTS AND DISCUSSION

The high seed production levels by annual ryegrass plants present within wheat crops at harvest indicates the importance of HWSC in preventing seed bank replenishment/establishment. Pre-harvest counts determined that the average annual ryegrass plant density present at harvest across the 25 trial sites was 10 plants m^{-2}, ranging from 1 to 26 plants m^{-2} (Table 1). These low to moderate infestations have persisted through weed control treatments during the growing season to mature with the wheat crop. Although plant densities were low to moderate annual ryegrass seed production was high. An indication of the importance of targeting at crop maturity is that in most instances surviving plants produced sufficient seed to establish or replenish a significant seed bank. Annual ryegrass seed production averaged over 2000 seed m^{-2}, but varied considerably (<100 to >5000 seed m^{-2}) across the 25 trial sites. Seed production by individual plants was also variable (28 to 425 seed $plant^{-1}$) indicating climatic, crop competition and weed control treatment effects. However, the average plant seed production of approximately 200 seed $plant^{-1}$ clearly indicates the potential for low annual ryegrass infestations to result in significant infestations in subsequent seasons. This level of seed production from just 1.0 plant m^{-2} will result in the production of 4 kg ha^{-1} of annual ryegrass seed (assuming a seed weight of 2 mg). During harvest this seed will subsequently be evenly spread (seeded) across the field by harvest residue spreading systems. Even with a 70–80% loss of viable seed due to predation, fatal germination and decay this seed production will potentially realise the establishment of 50 annual ryegrass plants m^{-2} next growing season. Thus not only is there a real opportunity, but an obvious need to intercept weed seed production at harvest using HWSC systems. It is only with reduced seed bank inputs that annual weed populations can be restricted to necessarily low levels.

HWSC treatments were similarly effective in targeting annual ryegrass seed during harvest. (Table 2). Across all 25 sites chaff cart, narrow windrow burning and HSD treatments each reduced (P <0.05) annual ryegrass emergence in comparison to the control treatment Chaff cart, narrow windrow burning and HSD treatments were all similarly effective (P >0.05) in targeting annual ryegrass seed at harvest resulting in equivalent reductions in subsequent annual ryegrass emergence (Table 2). All three HWSC systems target the weed seed bearing chaff fraction exiting the header during the harvest operation. Therefore, if chaff burning (chaff cart and narrow windrow) and chaff processing (HSD) are effective then it is expected that these systems will deliver the same effects on annual ryegrass populations.

The overall impact of HWSC treatments on annual ryegrass populations was varied and likely influenced by pre-harvest seed shed as well as pre-existing seed banks and early season rainfall. When averaged across all 25 sites, HWSC treatments resulted in a 56% reduction in subsequent autumn annual of ryegrass emergence. However, there was considerable variation in HWSC efficacy between sites with large reductions in annual ryegrass emergence of up to 90% (Arthurton) contrasting with reductions as low as 29% (Rand) (Table 2). There is an indication of a relationship between pre-harvest seed numbers and subsequent annual ryegrass emergence where lower

Table 2. Autumn annual ryegrass plant densities and emergence reductions due to HWSC treatments at 25 sites in Western (2010) and Eastern (2011) Australia.

	Treatment				
	Control	Chaff cart	Windrow burn	HSD	LSD
Location	Annual ryegrass (plants m^{-2})				(P = 0.05)
Binnu	21	12	7	11	5
Tenindewa	52	–[a]	17	21	31
Mingenew	33	17	23	18	5
Buntine	222	82	58	73	54
Wongan Hills	24	9	9	12	10
Wyalkatchem	106	54	45	52	30
Corrigin	11	4	3	3	5
Kondinin	208	98	133	139	66
Holt Rock	277	111	145	102	38
Kojonup	254	81	–	64	113
Broomehill	20	9	7	10	7
Minnipa	329	259	174	245	74
Minnipa	209	–	84	62	128
Cummins	425	145	144	162	236
Bute	89	43	46	44	25
Arthurton	12	3	1	2	9
Pinnaroo	174	93	55	55	80
Underbool	0.2	–	0.1	0.1	0.1
Dimboola	14	5	7	8	5
Dookie	4619	–	1663	2079	2027
Rand	238	161	170	148	61
Old Junee	2	–	1	1	1
Harden	1117	–	726	726	378
Peak Hill	358	–	179	158	65
Coonamble	208	–	98	109	77

[a] This treatment was not performed at this site.

pre-harvest annual ryegrass seed numbers also had larger proportional reductions in plant densities. In contrast, at sites where there were higher pre-harvest seed densities there was a reduced impact of HWSC systems on annual ryegrass emergence.

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