Is continuous wheat a viable rotation option when challenged by herbicide resistant annual ryegrass populations?

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Summary Integrated weed management (IWM) shows great promise for weed control in Western Australia, particularly where the weeds have developed herbicide resistance. Many growers would like to increase the number of years of wheat in their rotation cycle because it has a more stable return on investment over time than most other crop species.

The site at Katanning was established in 1999 and has been sown to wheat each season. The site comprises seven treatments, replicated three times. Each treatment is based on a standard practice with subsequent treatments including one or more IWM strategies such as increased seeding rates, stimulatory cultivations, split seeding, burning and alternative herbicides.

Burning dense, undisturbed stubble (not grazed over summer) proved to be an effective means of controlling annual ryegrass seeds.

Treatments that include a high crop seeding rate (150 kg ha^{-1}) and herbicides had lower levels of ryegrass carrying over from the previous year than treatments where the crop is seeded with a standard seeding rate (60 kg ha^{-1}). In 2000 yields were 20% higher on average when plots were burned compared to those plots, which were, raked (1920 vs. 1591 kg ha^{-1}).

Continuous wheat has remained a viable option after three years of investigation. Treatments that incorporate high crop seeding rates, herbicides and stubble burning have considerably lower annual ryegrass densities and have yielded well compared to other treatments in the experiment. The most profitable options tested have always included stubble burning
Keywords Integrated weed management, herbicide resistance, continuous wheat.

INTRODUCTION

Herbicide resistance has complicated weed management in the Australian (and the world's) broadacre cropping systems. Annual ryegrass (*Lolium rigidum* Gaudin) is one of our most serious weed problems and, to make it more interesting, annual ryegrass provides the greatest number of herbicide resistant weed populations in Australia (Preston *et al.* 1999).

Integrated weed management (IWM) combines multiple weed management techniques to reduce weed density, the idea being to manage weeds using a variety of control measures. In this way, the weeds are less likely to evade control (e.g. resistance to herbicides).

Many of the techniques extended for inclusion in IWM programs revolve around crop rotation, pasture phases and livestock grazing strategies. However, there are a significant number of growers who wish to remain in continuous crop or would prefer to crop only cereals – both are choices that may exacerbate the development of herbicide resistance. Cereals and wheat in particular have reliable long-term returns. Are there integrated weed management options for these growers?

This experiment aimed to assess the level of annual ryegrass control achievable in a continuous wheat rotation using IWM strategies.

MATERIALS AND METHODS

Site details The Katanning site was established in 1999 and comprises seven treatments (Table 1), replicated three times. Plot size is 11 m by 100 m. The site is located on a gravelly (10% gravel) surfaced dark grey duplex soil with a pH ($CaCl_2$) of 4.7. Average annual rainfall in Katanning is 482 mm with an average 362 mm falling in the May to October growing season.

Annual ryegrass seeds were collected in 1999 and submitted for a herbicide resistance test. Significant levels of resistance were detected to Glean® (80% survival). In addition, 20% of the annual ryegrass plants tested survived an application of glyphosate 1 L ha^{-1} (450 g a.i.).

Treatments The same treatments are imposed on the same plots each season. This site is seeded to wheat each year; Perenjori was the variety planted in 1999 and Westonia was planted in 2000 and 2001. All plots are seeded on the same day.

Seed catching was imposed on all plots at harvest in 1999. In the second year, summer rainfall delayed harvest until late January 2000. It is likely that a high proportion of the annual ryegrass seed was shed prior to harvest and so escaped chaff collection. Plots were split in autumn 2000. Half of the plots had the stubble raked from the plot and then burnt. The remaining half of the plots had the stubble burned *in situ*. The burning was repeated in autumn 2001.

Measurements The density of annual ryegrass was measured prior to crop establishment and during the

Table 1. The density (plants m^{-2}) of annual ryegrass present before the application of first knockdown (May 1999), following crop establishment (July 1999) and following autumn stubble treatments and crop establishment (August 2000 and July 2001).

No.	Treatment	1999		August 2000		July 2001	
		May	July	Raked	Burned	Raked	Burned
1	Standard Practice (workup, knockdown and seed @ 60 kg ha^{-1} with 100 kg ha^{-1} Agras + 40 kg ha^{-1} urea. 35 g ha^{-1} Logran® IBS)	944	135	460	93	147	9
2	High SR (increase seeding rate to 150 kg ha + 150 kg ha^{-1} Agras + 60 kg ha^{-1} urea) + Herbicides (35 g Logran + 2 L Avadex® + 1 L diuron IAS)	644	35	67	6	9	2
3	Tickle (knockdown, tickle, knockdown then seed) + Standard SR + Min Till (narrow points no 'workup')	877	188	242	18	114	4
4	Standard SR + Split Seeding (two seeding passes with half of seed in each pass)	1260	186	689	71	189	17
5	Tickle + High SR + Split Seeding + Herbicides	733	75	14	6	9	0
6	High SR + Min Till + Herbicides	755	90	150	71	9	1
7	Tickle + High SR + Split Seed + Min Till + Herbicides	1288	106	52	28	11	0
	LSD (P=0.05)	ns	78.3	261.2		53.5	

IBS = Incorporated by seeding, IAS = Immediately after seeding. Workup = cultivated to 10 cm with a scarifier.
Knockdown = Roundup™CT or Spray.Seed™ at 1–2 L ha^{-1} Tickle = Tyned cultivation 2–3 cm deep.
LSD = Least significant difference. Agras (17.5% N, 7.6% P, 17% S), urea (46% N).

growing season within the crop. Grass seed head density was measured before harvest to give an estimate of seed set. Grain yield, size and protein were recorded to assist in calculation of a gross margin.

RESULTS AND DISCUSSION

Treatments that include a high crop seeding rate (150 kg ha^{-1}) and herbicides, had lower levels of ryegrass carrying over from the previous year than treatments where the crop is seeded with a standard seeding rate (60 kg ha^{-1}) (Table 1). Similar effects have been reported previously (Peltzer 1999).

Burning dense, undisturbed stubble effectively controlled annual ryegrass seeds (Table 1). Raking the stubble from the plots probably increased the level of soil contact with seed and aided germination of the ryegrass. In a year with an early break of season this increased level of germination that could be controlled by mechanical or chemical means.

On average, wheat yields were 20% (2000) to 25% (2001) higher on burned compared to raked plots (Table 2). Burning the stubble in autumn outweighed the effect of the other weed management treatments imposed and there was little benefit gained from increasing the seeding rate on burned plots (Table 2). However, increasing the seeding rate and applying herbicides resulted in yield gains where higher densities of ryegrass were present on the raked plots.

This site was not grazed during the course of the demonstration. Stock were excluded over summer to ensure there was no disturbance to the stubble, little movement of ryegrass seeds and little loosening of the soil surface which may have increased the potential for soil movement, especially on the autumn burnt areas. Not all soil types are suitable for burning and burning should be avoided on sandplain soils and on exposed landforms. It is safer to burn windrows rather than entire paddocks, in this way more of the crop residue will be retained for soil and nutrient conservation.

Gross margin was linked most closely with yield. Treatments resulting in higher yields had higher gross margins (Table 3). However, where costs were increased through more management inputs, gross margin has declined despite equivalent yields.

There are more costs involved in producing an IWM crop. These costs include added or increased cultivation, higher seed/fertiliser inputs and more farm labour to put the crop in. However, despite this fact, it is important that the costs associated with IWM farming systems are considered when extending information on weed management options. It must also be remembered that if a grower has a strongly resistant annual ryegrass population, then income from affected paddocks will be severely limited and IWM one of the few options for producing a profitable crop.

It is too early to conclude whether it is possible to grow wheat after wheat for an extended period, maintain low populations of annual ryegrass (and other weeds) and minimise the cereal disease risk. This experiment is in its fourth year and already some treatments (treatments 1 and 4) are failing to achieve good weed control and crop yields are declining. These treatments are

Table 2. Wheat yield (t ha^{-1}) following harvest for the 1999, 2000 and 2001 growing seasons.

No.	Treatment	1999	2000		2001	
			Raked	Burned	Raked	Burned
1	Standard Practice (workup, knockdown and seed @ 60 kg ha^{-1} with 100 kg ha^{-1} Agras + 40 kg ha^{-1} urea. 35 g ha^{-1} Logran® IBS).	2.16	0.76	1.60	1.66	2.39
2	High SR (increase seeding rate to 150 kg ha + 150 kg ha^{-1} Agras + 60 kg ha^{-1} urea) + Herbicides (35 g Logran + 2 L Avadex® + 1 L diuron IAS)	2.59	1.86	2.08	2.39	2.57
3	Tickle (knockdown, tickle, knockdown then seed) + Standard SR + Min Till (narrow points no 'workup')	2.19	1.56	1.99	1.88	2.38
4	Standard SR + Split Seeding (two seeding passes with half of seed in each pass)	2.15	0.81	1.85	1.55	2.40
5	Tickle + High SR + Split Seeding + Herbicides	2.56	2.18	2.05	2.45	2.99
6	High SR + Min Till + Herbicides	2.49	1.91	1.83	2.09	2.50
7	Tickle + High SR + Split Seed + Min Till + Herbicides	2.55	2.07	2.03	2.48	2.95
	LSD (P=0.05)	0.39	0.65		0.74	

See Table 1 for legend.

Table 3. Gross margins 1999, 2000 and 2001 ($ ha^{-1}). Each gross margin was calculated using the costs and returns of the relevant growing season. Values in brackets are negative.

No.	Treatment	1999	2000		2001	
			Raked	Burned	Raked	Burned
1	Standard Practice (workup, knockdown and seed @ 60 kg ha^{-1} with 100 kg ha^{-1} Agras + 40 kg ha^{-1} urea. 35 g ha^{-1} Logran® IBS).	**233.76**	(89.58)	65.44	182.82	**347.06**
2	High SR (increase seeding rate to 150 kg ha + 150 kg ha^{-1} Agras + 60 kg ha^{-1} urea) + Herbicides (35 g Logran + 2 L Avadex® + 1 L diuron IAS)	**221.71**	15.04	58.06	242.95	287.51
3	Tickle (knockdown, tickle, knockdown then seed) + Standard SR + Min Till (narrow points no 'workup')	**226.23**	53.22	**133.17**	217.67	**333.29**
4	Standard SR + Split Seeding (two seeding passes with half of seed in each pass)	**218.88**	(93.16)	94.93	145.28	**336.36**
5	Tickle + High SR + Split Seeding + Herbicides	197.77	44.62	25.52	228.16	**353.24**
6	High SR + Min Till + Herbicides	**213.77**	35.52	26.74	190.04	283.88
7	Tickle + High SR + Split Seed + Min Till + Herbicides	189.67	37.88	35.40	236.52	242.68

See Table 1 for legend. Figures in bold are those with a gross margin >90% of best treatment.

being taken out of wheat for a season (2002) to enable a rotation to field peas for green manuring.

However, other treatments (treatments 2, 5, 6 and 7) continue to yield well with very low levels of annual ryegrass present. These treatments rely on increased crop seeding rates to give a competitive crop, herbicides, tickle cultivations to encourage weed germination prior to crop establishment, stubble burning and weed seed collection at harvest.

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