

East-west crop row orientation reduces annual ryegrass fecundity

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Summary Light is an important resource that crops and weeds compete for, and so increased light interception by the crop can be used as a method of weed control. This research investigated the impact of altered light availability (from crop row orientation or seeding rate) on the growth and fecundity of annual ryegrass. Cereal crops were sown in an east-west or north-south direction, at a high or low seeding rate, in three field trials in 2010 and 2011 (at Merredin, Wongan Hills and Katanning, WA). The average light available to annual ryegrass in the inter-row space of east-west crops at anthesis was 28%, compared to 53% in north-south crops. Reduced light availability in the east-west crops resulted in reduced annual ryegrass fecundity in five of the six trials (average of 2968 and 5705 seeds m⁻² in the east-west and north-south crops). Light availability was not influenced by seeding rate, but the high seeding rate reduced fecundity in three of the six trials (average of 3354 and 5092 seeds m⁻² in the crops with high and low seeding rate). Increased competitive ability of crops (through increased light interception or increased crop density) is an effective, environmentally friendly and inexpensive method of weed control.

Keywords Biomass, crop competition, photosynthetically active radiation, seed production, weed.

INTRODUCTION

Solar radiation is a key determinant of plant growth, with competition for light leading to reduced tillering of grasses (Ballare and Casal 2000). In a field crop agro-ecosystem, the intense competition for light suggests that minimising light availability to weeds (while maximising light availability to crops) will suppress weed growth (Ballare and Casal 2000, Zimdahl 2004). Physically orientating crop rows such that they shade the weeds in the inter-row space can substantially reduce weed biomass (Shrestha and Fidelibus 2005, Borger *et al.* 2010, Alcorta *et al.* 2011). The biomass of *Coryza canadensis* (L.) Cronq. (horseweed) was reduced by 30% in east-west orientated grapevines (*Vitis Vinifera* L.) (Alcorta *et al.* 2011). Likewise, the dry biomass and seed production of *Solanum nigrum* L. (black nightshade) was reduced in east-west

grapevines by 25% and 20% (Shrestha and Fidelibus 2005). Biomass of several weed species in east-west orientated wheat (*Triticum aestivum* L.) or barley (*Hordeum vulgare* L.) crop rows was reduced by 51% and 37% in Western Australia (WA). Concomitantly, wheat and barley yield was increased by 24% and 26% as a result of the reduced weed growth (Borger *et al.* 2010). However, this research was conducted in conditions of high weed density, without the application of alternative weed control methods. The impact of altered crop orientation on weed suppression in cereal crops when weeds are at moderate to low densities (i.e. weed densities found in commercial crops where herbicides are used) has not been investigated.

Increased plant density may also increase the competitive ability of crops, potentially due to increased light interception by high density crops (Stapper and Fischer 1990, Champion *et al.* 1998). Champion *et al.* (1998) found that increased wheat density increased inter-row shading and subsequently reduced the biomass of inter-row weeds. Conversely, Stapper and Fischer (1990) determined that the density of wheat plants had little impact on canopy size or shading of the inter-row space, because leaf area per plant decreased as plant density increased. However, light interception resulting from increased plant density has not been researched extensively.

The current study investigated the impact on inter-row annual ryegrass growth when cereal (wheat and barley) crops were planted in east-west or north-south crop row orientations, at high or low densities. Greater shading of inter-row annual ryegrass should occur in east-west crops compared to north-south crops, or crops sown at high rather than low density.

MATERIALS AND METHODS

Trial details Field trials were conducted on Department of Agriculture and Food WA (DAFWA) Research Stations at Merredin, Wongan Hills and Katanning, in 2010 and 2011. In 2010 the three trials investigated crop row orientation (east-west or north-south) and seeding rate (wheat cv. Wyalkatchem at 60 or 120 kg ha⁻¹). In 2011 the trials investigated orientation, crop type (wheat cv. Wyalkatchem or barley cv. Buloke)

and seeding rate (50 or 100 kg ha⁻¹). Trials were arranged in a split plot design, with orientation as the main plot factor and seeding rate or all combinations of seeding rate and crop type (for the 2011 trials) randomised within the subplots. Trials were replicated three times in 2010 and four times in 2011 (plot size of 2 m by 20 m).

At all sites non-selective herbicides were used to kill weeds that emerged prior to crop seeding. The crops were seeded (on 31 May 2010 and 27 May 2011 at Merredin, 11 June 2010 and 16 June 2011 at Wongan Hills, and 24 May 2010 and 24 June 2011 at Katanning), using a no tillage seeding system (knife points and press wheels), with a crop row spacing of 25 cm, at a depth of 3–4 cm, with 80–100 kg ha⁻¹ of fertiliser (Agras 14, 14, 9.6, 0.04% N:P:S:Zn or CropStar 15, 14, 10% N:P:S). Selective herbicides or pesticides were applied in crop where necessary to remove weeds other than annual ryegrass or crop pests. At all sites, annual ryegrass was the dominant growing season weed and there were few other weeds to control. Crops were harvested on 15 November 2010 and 23 November 2011 at Merredin, 10 November 2010 and 30 November 2011 at Wongan Hills, and 1 December 2010 and 5 December 2011 at Katanning.

Measurements Photosynthetically active radiation (PAR) was sampled at anthesis, at mid-day at the centre of the inter-row space, with a linear Ceptometer (Sunfleck Ceptometer Delta-T Devices LTD, 128 Low Road, Burwell, Cambridge CB5 0EJ, England) (Percy 1991). Within each plot PAR was measured above the crop canopy and above the weed canopy. The PAR available to the annual ryegrass canopy in the inter-row space was expressed as a percent of total PAR available to the crop canopy. Above ground biomass of annual ryegrass was harvested from 50 cm by 50 cm quadrats at senescence, dried at 40°C for three days, weighed, threshed and put through a splitter to get a consistent sample weighing approximately 5 g. Seeds in each sample were manually counted and total dry biomass m⁻² was used to estimate seed production from the number of seeds in the subsample. Total crop yield per plot was recorded at harvest.

Statistical analysis Variates were analysed using ANOVA in a split plot model, with orientation as the main plot factor, seeding rate (2010) or seeding rate by crop type (2011) as the subplot factors and replication included as the blocking factor. Means were separated using Fisher's protected least significant difference (LSD). To ensure normal distribution of the residuals, a square root transformation was applied to the Merredin 2010, Merredin 2011 and Katanning 2011

biomass data and the Wongan Hills 2010, Katanning 2010, Merredin 2011 and Katanning 2011 seed production data. Where transformations were performed, data are presented as back-transformed means (VSN International 2012).

RESULTS

Photosynthetically active radiation East-west crop row orientation generally reduced the PAR available to annual ryegrass at anthesis, although the difference was not significant at Merredin or Katanning in 2010 (Table 1). Crop type and seeding rate did not influence PAR availability.

Annual ryegrass biomass Annual ryegrass biomass was very low at all sites in 2010 and at Merredin 2011. Orientation consistently had no significant impact on biomass. Biomass was significantly reduced in barley compared to wheat at Merredin 2011 (0.1 and 1.4 g m⁻², P < 0.001, LSD: 0.2) and Katanning 2011 (136 and 174 g m⁻², P: 0.016, LSD: 1.5). The high seeding rate reduced biomass at Wongan Hills 2011 (51 and 71 g m⁻², P: 0.034, LSD: 19) and Katanning 2011 (141 and 168 g m⁻², P: 0.007, LSD: 1.5).

Annual ryegrass seed production Annual ryegrass seed production was significantly reduced in east-west crops compared to north-south crops at all trial sites except Katanning 2010, reduced in barley crops compared to wheat crops at Merredin 2011 and Katanning 2011, and reduced by high crop density at Merredin 2010, Merredin 2011 and Katanning 2011 (Table 2).

Table 1. The percent of photosynthetically active radiation available to annual ryegrass in the inter-row space of east-west or north-south orientated crops of wheat (2010) or wheat and barley (2011). Means are separated by least significant difference (LSD, where NS indicates there is no significant difference).

Year	Trial	East-west	North-south	LSD (P < 0.05)
2010	Merredin	57	79	NS
	Katanning	19	40	NS
	Wongan Hills	27	63	12.9
2011	Merredin	7	21	3.4
	Katanning	27	54	17.9
	Wongan Hills	28	62	20.7

Table 2. Annual ryegrass fecundity (seeds m⁻²) in east-west or north-south orientated crops of wheat (2010) or wheat and barley (2011), with low or high seeding rates. Means are separated by least significant difference (LSD, where NS indicates no significant difference).

Treatments	2010			2011		
	Merredin	Wongan Hills	Katanning	Merredin	Wongan Hills	Katanning
East-west	503	24	529	27	2610	14,113
North-south	910	300	465	125	6155	26,276
LSD (P<0.05)	331	36	NS	35	3469	1342
Barley	*	*	*	19	4420	16,410
Wheat	*	*	*	146	4345	23,378
LSD (P<0.05)				18	NS	271
Low seeding rate	1032	130	151	119	5029	24,087
High seeding rate	381	21	132	30	3736	15,826
LSD (P<0.05)	275	NS	NS	18	NS	271

Crop yield Yield was greater in east-west crops compared to north-south crops at Merredin 2011 (2957 and 2589 kg ha⁻¹, P: 0.019, LSD: 22) and greater in high rather than low seeding rate plots at Wongan Hills 2011 (2793 and 2491 kg ha⁻¹, P: 0.008, LSD: 218) and Katanning 2011 (2244 and 1840 kg ha⁻¹, P <0.001, LSD: 174). Wheat crops had a greater yield than barley at Merredin 2011 (2992 and 2554 kg ha⁻¹, P <0.001, LSD: 98) and Wongan Hills 2011 (3082 and 2202 kg ha⁻¹, P <0.001, LSD: 218), but reduced yield at Katanning 2011 (1813 and 2271 kg ha⁻¹, P <0.001, LSD: 174).

DISCUSSION

East-west orientated crop rows reduced the PAR available to annual ryegrass compared to north-south crop rows, and reduced annual ryegrass fecundity. Katanning in 2010 was the only site where crop row orientation had no impact on annual ryegrass fecundity. However, there was late emergence of annual ryegrass at this site, improving the competitive ability of the crop. Crop orientation consistently had no significant impact on annual ryegrass biomass. A plants' response to an altered light environment may be to alter biomass allocation (stem elongation, altered leaf distribution etc.) but this does not necessarily reduce total biomass (Ballare and Casal 2000 and Page *et al.* 2010). Borger *et al.* (2010) found that cereal crop orientation could reduce weed biomass in some seasonal conditions, but weed density was higher in those trials. In conditions of exceptionally high weed density, where no herbicides are applied, the competitive ability of the crop is poor (due to early competition with weeds).

As a result, most weed control techniques will reduce weed growth while improving crop yield. The current trials had medium to low weed density, as might occur in a normal commercial crop where herbicides are applied, and so the crop was more competitive regardless of orientation. However, while shading may not reduce weed biomass, it does consistently reduce tiller production in grasses and may reduce fecundity (Ballare and Casal 2000), as found in the current study. As there was little impact on weed biomass, east-west crop orientation only increased yield at Merredin 2011. However, increased yield at one site in six is still a positive result for growers, given the low cost of implementing this weed control technique, combined with the long term economic benefits of reduced annual ryegrass fecundity.

The barley in Merredin 2011 and Katanning 2011 had reduced biomass and fecundity of annual ryegrass. Wheat and barley generally have similar competitive ability against annual ryegrass, dependent on cultivar and seasonal conditions (Lemerle *et al.* 1995).

Increased seeding rate did not affect light availability. This confirms the results from Stapper and Fischer (1990), who determined that the density of wheat plants had little impact on the canopy size and shading. However, it did increase the competitive ability of the crop leading to reduced biomass at the two sites with greatest weed biomass and reduced fecundity in three of the six sites. Traditional models of crop/weed competition suggest that increased plant number at the seedling stage may lead to reduced biomass and fecundity of individual plants, as was observed in the current research (Zimdahl 2004).

Crop competition remains one of the most economically desirable and environmentally sustainable methods of weed control. The validity of crop row orientation as a weed control technique will depend on the latitude of individual farms and the crop/weed species within the agronomic system (Mutsaers 1980, Borger *et al.* 2010). Further, it may not always be practical to apply, as it is difficult to drive directly into the sunrise/sunset if growers do not have autosteering technology. However, the current research highlighted that improved crop competition can effectively reduce annual ryegrass fecundity.

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