Increasing wheat sowing rates can reduce winter weed numbers in a cotton-wheat rotation

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Abstract

Wheat is commonly sown in rotation with cotton in Australian cotton farming systems. Uncontrolled weed growth can inhibit wheat growth and thereby, have a detrimental effect on the following cotton crop. Weeds that are frequently found in wheat crops of north-western New South Wales (NSW) include deadnettle (*Lamium amplexicaule* L.), sow thistle (*Sonchus oleraceus* L.), and annual Phalaris (*Phalaris paradoxa* L.). The objective of our study was to quantify the effects of wheat sowing rates on weed populations and growth, and their impact on wheat growth and yield. An experiment that consisted of wheat sowing rates of 0 (fallow), 30, 60, 120 and 180 kg ha^{-1} was conducted during 2014 and 2015. Weed biomass, type (broad-leaved or grassy), and species diversity were assessed at wheat anthesis. Wheat phenological events (emergence, anthesis, maturity dates) were recorded and wheat biomass measured at 10 weeks after sowing (2015) and anthesis (2014, 2015), as well as grain yield. Weed populations at wheat anthesis consisted of broad-leaved weeds during 2014 and a mix of broad-leaved and grassy (annual Phalaris) weeds during 2015. Weed biomass decreased sharply when wheat was sown, even at the lowest sowing rate of 30 kg ha^{-1} and continued to decrease such that at the higher sowing rates it was negligible. Adequate yields can be attained by sowing wheat at rates in the range 30-60 kg ha^{-1}. The costs associated with sowing at higher rates cannot be justified, although significant long-term reductions in the weed seedbank are likely only by sowing at these rates.

Key Words

Cropping system; Vertosol; Irrigation; Australia; Deadnettle; annual Phalaris

Introduction

Wheat (*Triticum aestivum* L.) is commonly sown in rotation with cotton (*Gossypium hirsutum* L.) in Australian cotton farming systems (Hulugalle and Scott, 2008). Biotic and abiotic factors that inhibit wheat growth can have a detrimental effect on the following cotton crop. One such biotic factor is the uncontrolled growth and proliferation of weeds. Weeds that are frequently found in wheat crops of northwestern New South Wales (NSW) include broad-leaved weeds such as deadnettle (*Lamium amplexicaule* L.), sow thistle (*Sonchus oleraceus* L.) and wire weed (*Polygonum aviculare* L.), and grassy weeds such as annual Phalaris (*Phalaris paradoxa* L.). Some of these weeds may also have direct inhibitory effects on the following cotton crop as they are alternative hosts for insect pests such as the two-spotted spider mite (*Tetranychus urticae* Koch) (Wilson, 1995) and seedling diseases such as black root rot of cotton (Anonymous, 2015). Uncontrolled growth of these weeds can, therefore, result in significant growth and yield reductions in both cotton and winter rotation crops (Brooke and McMaster, 2018; Johnson, 2017). Typical weed control practices include pre-sowing cultivation and/or herbicide application. Post-wheat emergence herbicide applications do not occur 6 weeks after sowing. In addition to the occurrence of herbicide resistance, the residues of herbicides commonly used such as diuron, glyphosate and trifluralin (Brooke and McMaster, 2018; Johnson, 2017) can remain in soil for extended periods or enter in to waterways, thus degrading natural and agricultural ecosystems (McHugh *et al*., 2008). An alternative and effective method of weed control is to increase crop sowing density (Lemerle *et al*., 2004). The advantage of this method is that it can reduce or eliminate the application of the abovementioned herbicides, thus not only reducing production costs but also the impacts of herbicide residues on natural and agricultural ecosystems.

Depending on whether the cropping system in place is irrigated or dryland, wheat sowing rates in north-western NSW range from approximately 25 to 60 kg ha^{-1}. We hypothesised that increasing wheat sowing rates from those currently used may reduce or eliminate many common weed species. The objective of our study was to quantify the effects of wheat sowing rates on weed populations and growth, and their impact on wheat growth and yield in a cotton farming system of north-western NSW.

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Methods

Experimental site

The experimental site was located at the Australian Cotton Research Institute, near Narrabri (149°47′E, 30°13′S), northwestern NSW, Australia that had been under a cotton-wheat rotation (cotton-wheat-summer/winter fallow-cotton) for several years in which wheat had been sown at a rate of 60 kg ha^{-1}. This site also had a history of high deadnettle infestation. Narrabri has a sub-tropical semi-arid climate with a mild winter and a hot summer. The hottest month is January (mean daily maxima and minima of 34.3 and 20 °C, respectively) and July is the coolest (mean daily maxima and minima of 17.8 and 4 °C, respectively). Mean annual rainfall is 568 mm. The soil at the experimental site was a deep uniform grey clay and was classified as a very fine grey Vertosol (Isbell, 2002). Mean particle size distribution in the surface 1 m was: 64 g 100 g^{-1} clay, 11 g 100 g^{-1} silt and 25 g 100 g^{-1} sand, pH in 0.01M $CaCl_2$ 7.5, and $EC_{1:5}$ 0.29 dS m^{-1}.

Experimental layout and crop management

The experiment was conducted during the winters of 2014 and 2015 and consisted of wheat sowing rates of 0 (fallow), 30, 60, 120 and 180 kg ha^{-1} arranged in a randomised complete block design with three replications. Each replicate included two fallow plots. The crop sequence during the experiment was cotton-wheat (2014)-summer fallow-wheat (2015). Individual plots were 20 m long and 8 rows wide. The rows (beds) were spaced at 1 m intervals with vehicular traffic being restricted to the furrows. Cotton was picked during late April or early May with a two-row picker after defoliation in early April. After cotton picking, the cotton was slashed and incorporated into the beds with a disc-hiller (to facilitate Heliothis moth (*Helicoverpa* spp.) pupae destruction. Average depth of incorporation was of the order of 0.10 m. Wheat (cv. Crusader) was sown 30-40 mm deep and a row spacing of 0.25 m on 26 May 2014 and 27 May 2015 with a 4-row air seeder pulled by a John Deere® JD8235R tractor at a density of 86, 171, 343 and 514 seeds m^{-2} corresponding to seed rates of 30, 60, 120 and 180 kg ha^{-1}, respectively. Wheat was sown on beds and sides of bed/furrows resulting in 3 rows in total; *viz*. one on the centre and two on either side of the bed. Weed emergence occurred 5-6 weeks after wheat was sown. The experiment was furrow-irrigated with 100 mm of water on 11th June 2014 and 29th May 2015. Fertiliser was applied as urea at a rate of 20 kg N ha^{-1} before sowing and 80 kg N ha^{-1} during August 2014 and July 2015.

Weed and wheat growth

Weed biomass, type (broadleaf or grass), and species diversity were assessed at weed emergence (not reported) and wheat anthesis. Wheat phenological events (emergence, anthesis, maturity dates) were recorded and wheat biomass measured at 10 weeks after sowing (2015) and anthesis (2014, 2015). Weed and wheat biomass were sampled using a randomly placed 1 m^2 quadrant in each of the 18 plots, oven-dried at 67°C for 72 h and dry weight recorded. Wheat grain yield was assessed by manual harvesting 1 m^2 in each of the wheat planted plots and threshing with a mini mechanical thresher.

Data analyses

All data were subjected to analysis of variance using a randomised block design with means and standard errors of the means determined using Statistix 10® software (https://www.statistix.com). Regression analyses were conducted between the biomass of weeds and wheat at anthesis and 9-10 weeks after sowing, and wheat grain yield.

Results

Weed species composition at wheat anthesis

Weed populations at wheat anthesis consisted of broad-leaved weeds during 2014 and a mix of broad-leaved and grassy weeds during 2015. Although total weed biomass differed among treatments during 2014 (Table 1), species distribution was similar with 96% of weed biomass consisting of deadnettle and 4% sow thistle. During 2015, however, weed populations at wheat anthesis were spatially variable (among replicates) with broad-leaved weeds accounting for an average of 6% of total weed biomass in replicate 1, 10% in replicate 2 and 30% in replicate 3, with values in individual plots ranging from 0 to 80%. Among the broad-leaved weeds, deadnettle dominated in most plots (98-100%), except in a single plot where it accounted for 50%, and wireweed 50%. Grassy weeds (annual Phalaris), therefore, dominated during 2015. Treatment effects were not discernible on weed species during 2015. The differences in species composition between the two seasons may be due to differences in water availability. Wheat was sown immediately after cotton during 2014, and hence there was no fallow and little water stored, whereas during 2015 it was sown after a summer fallow that had received 395 mm of rainfall (December 2014-May 2015). Water availability can cause changes to species composition of weed populations in semi-arid ecosystems, with drier conditions generally favouring broad-leaved species (Zimdahl, 1993).

Weed and wheat biomass, and wheat grain yield

Weed biomass decreased markedly when wheat was sown, even at the lowest sowing rate of 30 kg ha^{-1} and continued to decrease such that at the higher sowing rates it was negligible (Table 1). During 2014, there were no significant differences in the 60 to 180 kg ha^{-1} sowing range. During 2015, however, it was only the range 120-180 kg ha^{-1} that significant differences were absent and weed biomass was negligible. In summary, during years of restricted water availability when deadnettle was the predominant weed, a wheat sowing rate of 60 kg ha^{-1} was required to control weeds but in years of greater water availability when both broad-leaved and grassy weeds were present, higher sowing rates were required.

Weed biomass and growth in the fallow plots were around 6 times greater during 2014, even though there was more water available during 2015. This may partly be a reflection of the absence of grassy weeds and dominance of broad-leaved weeds during 2014. Wheat biomass in all treatments also decreased by an average of 39%. This may be due to residual fertiliser N from the preceding cotton season contributing to enhanced growth of wheat and weeds during 2014 (Hulugalle, 2005), whereas the fallow during 2015 summer ensured that there was no residual fertiliser. The greater solar irradiance and warmer daytime temperatures during June and July 2014 (Table 1) may also have contributed to the better weed and wheat growth during 2014.

Table 1. Effect of wheat sowing rate on weed biomass, and wheat growth and yield during 2014 and 2015 (means and standard errors of the means). WAS, weeks after sowing, n.s., non-significant

2014

Sowing rate (kg ha^{-1})	Sowing density (seeds m^{-2})	Weed biomass at wheat anthesis (kg ha^{-1})[a]	Wheat biomass at anthesis (t ha^{-1})	Wheat grain yield (t ha^{-1})
0 (control)	0	1300 (7.245 ± 0.1875)	-	-
30	86	129 (5.435 ± 0.2651)	7.1 ± 0.24	3.0 ± 0.42
60	171	55 (5.044 ± 0.2651)	7.7 ± 0.24	4.0 ± 0.32
120	343	0 (4.605 ± 0.2651)	7.4 ± 0.24	3.3 ± 0.32
180	514	55 (5.041 ± 0.2651)	7.9 ± 0.24	3.3 ± 0.32
P <		(0.001)	n.s.	n.s.

[a]Values in parentheses are $\log_e$ transformed values of x+100 where x is the untransformed value

2015

Sowing rate (kg ha^{-1})	Sowing density (seeds m^{-2})	Weed biomass at wheat anthesis (kg ha^{-1})[b]	Wheat biomass 10 WAS (t ha^{-1})	Wheat biomass at anthesis (t ha^{-1})	Wheat grain yield (t ha^{-1})
0 (control)	0	202 (5.313 ± 0.3163)	-	-	-
30	86	189 (5.249 ± 0.4474)	0.5 ± 0.13	4.1 ± 0.33	3.4 ± 0.24
60	171	45 (3.826 ± 0.4474)	1.1 ± 0.13	4.4 ± 0.33	3.7 ± 0.24
120	343	1 (0.732 ± 0.4474)	1.7 ± 0.13	4.6 ± 0.33	4.0 ± 0.24
180	514	2 (1.099 ± 0.4474)	1.9 ± 0.13	5.5 ± 0.33	3.4 ± 0.24
P <		(0.001)	0.01	n.s.	n.s.

[b]Values in parentheses are $\log_e$ transformed values of x+1 where x is the untransformed value

Wheat biomass at anthesis and grain yield did not differ significantly among wheat sowing rates during 2014 and 2015 but did so at 10 weeks after sowing during 2015 (Table 1). The absence of any significant effect of the wheat sowing rates in the mature crop may be related to an increase in intra-specific and within-plant inter-tiller competition for light (Evers *et al*., 2006). Evers *et al*. (2006) reported that cessation of tillering by wheat as population increased was induced when the fraction of photosynthetically active radiation (PAR) intercepted by the canopy exceeded a threshold range of 0.40-0.45, and the red:far-red ratio fell below 0.35-0.40. It is probable that intra-specific light competition did not become an inhibitory factor until later in the growing season when tillering increased. Grain yield was, thus, influenced more by intra-specific than by inter-specific competition as wheat was able to outcompete the weed species at this site. Regression analysis did not indicate the existence of any significant relationships between weed biomass and wheat biomass at anthesis in treatments sown with wheat (R^2 values of 0.06 during 2014, and 0.08 during 2015) but a significant relationship was present (R^2 =0.46*) during the early stages of crop growth, *viz*. 10 weeks after sowing during 2015. This indicates that weed growth inhibited wheat vegetative growth only for a limited period during the early growth of the crop and grain yield was unaffected. Adequate yields can be attained with sowing rates in the range 30-60 kg ha^{-1} instead of incurring the additional costs involved in sowing at higher rates. Sowing and fertiliser costs ranged from \$101 ha^{-1} for a sowing rate of 60 kg ha^{-1} to \$209 ha^{-1} for 180 kg ha^{-1} whereas the average value of wheat grain in this site was of the order of \$965 ha^{-1}. However, significant long-term reductions in the weed seedbank are likely only by sowing wheat at higher rates. This is because even a small weed population can ensure that the weed seedbank is maintained into the future. Under suitable conditions, an exponential increase in weed numbers can occur from even a small or moderate seedbank in the soil. This can present significant risks, especially with the emergence of herbicide resistant weeds.

Conclusions

Weed populations at wheat anthesis were consisted of broad-leaved weeds during 2014 and a mix of broad-leaved and grassy weeds during 2015. Wheat growth was inhibited by the weeds at this site only during its early vegetative stages whereas later vegetative growth and grain yield were not. Adequate yields can be attained by sowing wheat at rates in the range 30-60 kg ha^{-1}. The costs associated with sowing at higher rates cannot be justified at this site, although significant long-term reductions in the weed seedbank are likely only by sowing at these rates and this may be necessary in the future with the rise of herbicide resistant weeds.

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