Stability of competitive ability in wheat genotypes across different weed species

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Abstract

In the field, weeds are invariably present as a mixture of different species. Therefore, in developing crops with improved competitive ability (CA) with weeds, it is critical to determine the stability of CA against different weed species. During 2009, 14 wheat genotypes varying in CA were grown in weed-free and weedy plots to assess their tolerance to and suppression of three weed species, annual ryegrass (*Lolium rigidum*), oat (*Avena sativa*) and mustard (*Brassica juncea*). The suppression of weed seed production across the three weed species was strongly correlated (*r*= 0.86-0.90), indicating consistent weed species response to wheat genotypes. As compared to the cultivar Wyalkatchem, the most suppressive wheat genotype reduced weed seed production by up to 92% (mustard), 65% (ryegrass) and 53% (oat). The degree of weed tolerance of wheat genotypes varied with weed species, with grain yield losses ranging between 3-21% in mustard, 18-49% in ryegrass and 39-63% in oat. However, the ranking of wheat genotypes against the three weed species was maintained, as indicated by the significant correlations between wheat grain yield losses caused by each of the weeds (*r* = 0.58-0.77). There was a positive correlation between weed tolerance and suppression for each of the three weeds, ryegrass (0.79), oat (0.72) and mustard (0.59), suggesting that a genotype with high tolerance to weeds was also likely to have high suppressive ability.

Key Words

Integrated weed management, weed suppression,

Introduction

Weed management in many cropping systems in Australia has been heavily reliant on the use of selective herbicides. However, rapid evolution of herbicide resistance across multiple modes of actions and weed species has forced many growers in southern Australia to consider adoption of more integrated strategies for weed population management. In some districts, weeds such as annual ryegrass can no longer be controlled with selective post-emergence herbicides, thus further increasing reliance on pre-emergent herbicides. In such cropping systems, weeds that escape pre-emergent herbicide application can produce large amounts of seed due to poor competitive ability of current wheat cultivars. Integration of weed competitive crop cultivars with other control techniques such as crop-topping and wind-row burning has the potential to significantly improve effectiveness of weed management programs.

Wheat is known as a poor competitor enabling weeds surviving various control tactics including herbicides to set a large amount of seed (Lemerle *et al*. 1995). Therefore improvements in the competitive ability of wheat could reduce weed seed set and the dependence on herbicides in the cropping rotation. As farmer fields are often infested with mixed weed flora, such competitive cultivars would need to provide suppression of a range of weed species. In order to address this research question, a field study was undertaken to investigate the competitive ability of high vigour wheat lines against ryegrass, oats and mustard.

Methods

A field experiment was undertaken at Roseworthy, South Australia during 2009 to investigate the stability of competitive ability in wheat across different weed species. Fourteen wheat lines varying in competitive ability were used including nine breeding lines that have increased early vigour, an important plant trait in competitiveness (Seavers and Wright 1999). Ryegrass (*Lolium rigidum*), cultivated oat (*Avena sativa*) and oriental mustard (*Brassica juncea*) were used as the weed species in this study. The weeds were spread on the soil surface prior to the wheat being sown. All weeds were sown in monocultures, ryegrass was sown at 250 plants m^{-2}, oat (weed mimic for wild oat) at 60 plants m^{-2} and mustard (weed mimic for wild radish) at 30 plants m^{-2}. These densities were chosen to target 50% yield reduction in commercial wheat cultivars (Poole and Gill 1987; Streibig *et al*. 1989). Wheat was sown using knife points on 25cm row spacings. Plots were 3 by 1.5m and wheat seeding rates were adjusted according to the seed size of each line, targeting a density of 200 plants m^{-2}. All wheat lines were also sown without any weeds and with each of the three weed species in separate plots in a strip-plot design.

Plant density was recorded for both wheat and all weed species. Just prior to grain harvest within the plots containing weeds, spike density was recorded for ryegrass, panicle density for oats and plant density for mustard. Ryegrass seed set was calculated by randomly sampling plants and measuring the length and seed number of each spike. Seed number was then plotted against spike length and used as a calibration equation for ryegrass seed set, $y=7.7356x$, where y= seed number and x= average spike length (r^2= 0.93). Ryegrass spikes were then randomly sampled from each plot to determine the average length, and using the equation in combination with spike density, ryegrass seed set was calculated. Mustard seed set was measured by collecting all plants in each plot at maturity and after cleaning the seed it was weighed and grain size recorded to estimate seed production. Oats were harvested with the wheat using a plot harvester and later separated from the wheat using a seed grading machine. Once separated oats were weighed and grain weight recorded for an estimation of seed production.

The experiment was blocked in three replications and within each block plots were randomly allocated to each wheat line. Then each wheat plot was further randomly sub-divided into four strips within each block for each weed and a weed-free strip. All statistical analyses were completed using the GENSTAT statistical analysis software.

Results

Wheat grain yields varied significantly between the lines. In the plots containing no weeds yields ranged from 4.7t/ha to 2.7t/ha, averaging 3.5t/ha across all wheat lines (Table 1).

Table 1. Effect of wheat genotypes varying in competitive ability on grain yield and weed seed-set in the presence of annual ryegrass (ARG), mustard (MUS) and oat (OAT). (WF denotes crop in weed-free environment)

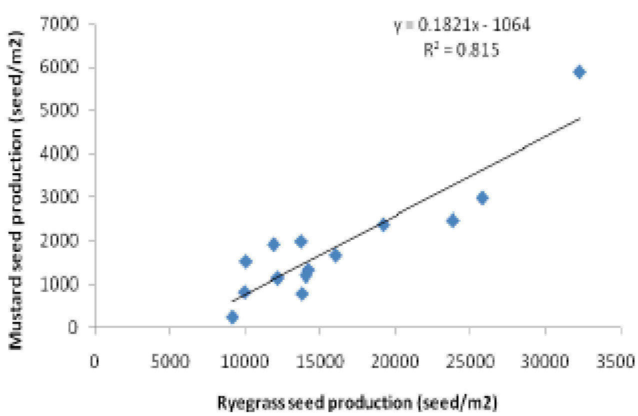
Line ID	Wheat grain yield (kg/ha)				Grain yield loss (%)			Weed seed production (seed/m^2)		
?	ARG	MUS	OAT	WF	ARG	MUS	OAT	ARG	MUS	OAT
Espada	2999	3978	2270	4497	30.7	10.1	47.4	19201	2379	1088
Frame	2218	2921	1894	3031	27.0	4.3	39.0	13715	1986	1079

Halberd	2167	3043	1479	3433	36.4	11.7	57.0	14202	1319	1392
Janz	2196	3230	1487	3653	37.6	10.3	58.3	23824	2473	1737
WCD1-0375	2779	3383	2014	3945	27.7	13.0	48.0	11898	1916	1423
WCD1-1462	2601	3285	1918	3542	28.2	7.8	46.8	13780	781	1088
WCD1-2204	2271	2629	1684	2968	23.5	11.5	43.8	14043	1194	1033
WCD2-110615	2557	3303	1787	4057	34.6	16.6	54.6	16012	1661	854
WCD2-280504	2826	3096	1742	3467	18.0	10.1	48.9	9961	819	828
WCD2-390403	2390	3012	1868	3438	30.5	12.1	45.9	9145	233	820
WCD2-400107	1826	2603	1276	2722	31.3	2.7	51.0	12148	1136	852
WCD2-400203	2325	2674	1720	3065	25.3	14.0	44.7	10030	1517	838
WCD2-420403	2085	2837	1329	3603	41.9	20.9	62.9	32262	5884	2245
Wyalkatchem	2419	3750	2054	4676	48.6	20.6	56.9	25797	2975	1708
Mean	2404	3125	1752	3578	32	12	50	16144	1877	1213

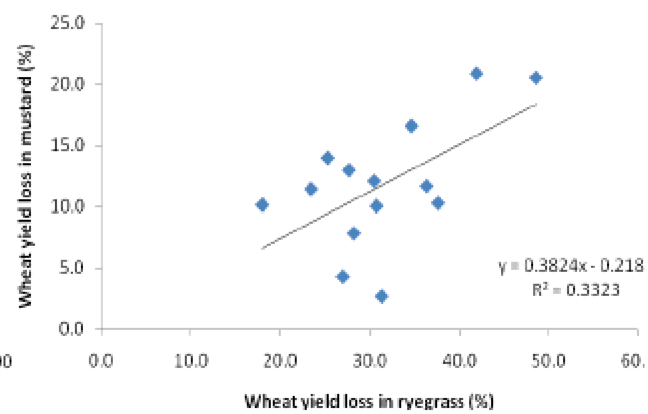
***P* values**			
Line ID	*** (555)	*** (8.25)	*** (2041)
Weed	*** (335)	*** (3.72)	*** (920)
Line ID.Weed interaction	*** (647)	ns	*** (3473)

*** *P*<0.001, values in parenthesis represent LSD

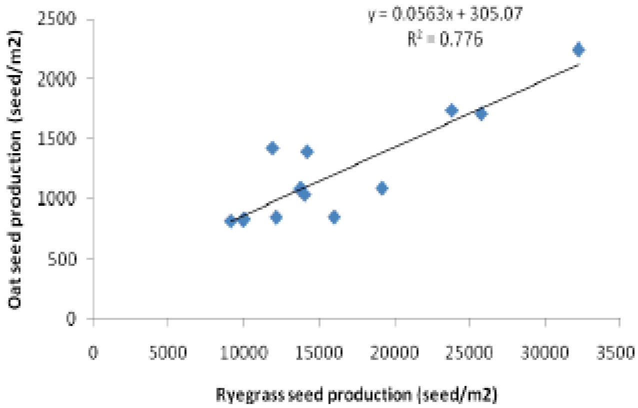
Most of the commercial varieties out-yielded the experimental high vigour lines. In the presence of weeds yields were significantly reduced in all lines except in the presence of mustard, where yields were not significantly lower than the weed-free treatment for many lines. Weed competition pressure was greatest under oats, with yield penalties, ranging from 39-63%. Yield losses from ryegrass ranged between 18-49% and between 3-21% for mustard. Despite actual grain yield losses varying significantly between weed species, wheat lines ranked similarly between weeds. This is indicated by significant positive correlations between yield losses caused by each of the three weeds, with *r* values ranging between 0.58 and 0.77, shown in Figure 1. This relationship indicates that despite changing the weed species, a wheat line showing high tolerance to ryegrass will also have high tolerance to oats and mustard. Wyalkatchem suffered consistently severe yield losses across all weed species. It is difficult to identify any wheat line with consistently high weed tolerance due to considerable variation in yield losses. The other component of competitive ability, weed suppression provided a much more consistent pattern of performance of wheat lines across the three weed species.



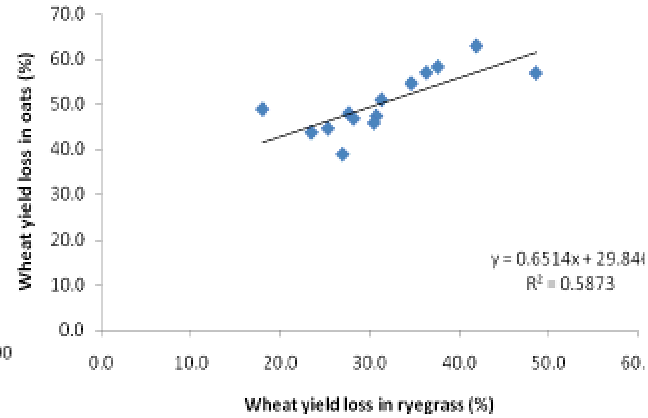
a.(i)



a.(ii)



b.(i)



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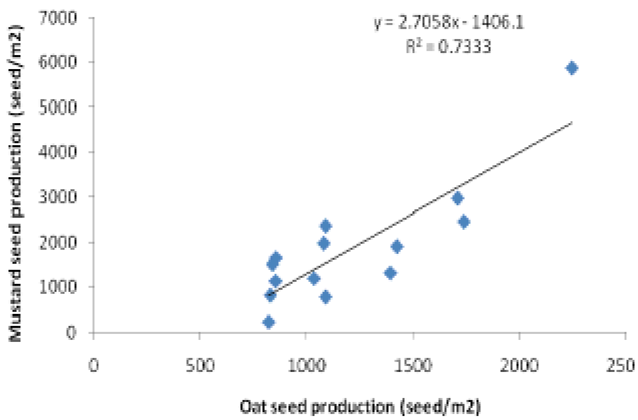
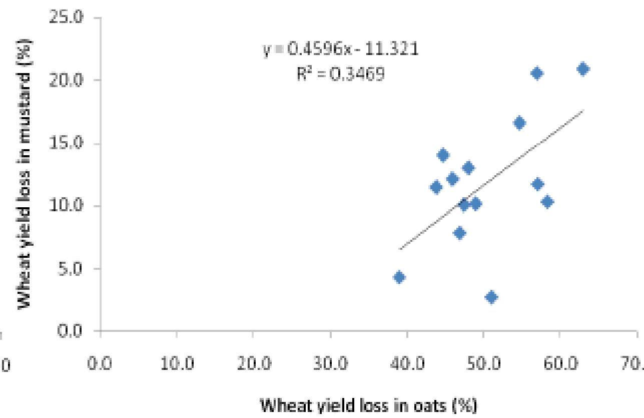


c.(i)



c.(ii)

Figure 1. Relationships for (i) weed seed production and (ii) wheat yield losses between three weed species used in this study, (a) ryegrass and mustard, (b) ryegrass and oat, and (c) oat and mustard. Significant correlations also were found between weed seed production and wheat yield loss in each weed species with r values of 0.79 in ryegrass, 0.72 in oat and 0.59 in mustard.

Weed seed production varied between weeds due to inherent differences between them in potential seed set. On average ryegrass produced 16000 seeds/m^2, compared to 1900 seeds/m^2 and 1200 seeds/m^2 for mustard and oat respectively. Rankings of lines based on weed suppression was much more consistent between weeds than weed tolerance, which is supported by a significant interaction between wheat line and weed species as well as highly significant correlations of seed production between each of the weeds (Figure 1). (*r* values: ARG/MUS=0.90, ARG/OAT=0.88, OAT/MUS=0.86). These results clearly demonstrate that the CA of a specific wheat line is consistent across weed species, whether it's a grass or broad-leaf species. Although the high vigour breeding lines did not show considerable advantages in terms of crop tolerance, they showed superior weed suppression as compared to the commercial cultivars used in this study. These results indicate that wheat lines with improved CA used in this study may not provide greater economic returns in the presence of weeds through achieving lower yield losses. However, these weed competitive wheat lines will assist in reducing the weed burden in future crops and could reduce dependence on herbicides. Wyalkatchem allowed for the highest weed seed set, with the exception of the extreme dwarf line, WCD2-420403 (Table 1). WCD2-390403 was consistently the most competitive breeding line with lowest weed seed production in each of the weed species. This high vigour lines reduced weed seed production by 92%, 65% and 53% in mustard, ryegrass and oat when compared to seed production of these species grown in competition with Wyalkatchem.

The crop yield loss (weed tolerance) and weed seed production (weed suppression) have been shown to be positively correlated in some studies (Lemerle *et al*. 2006), but they may also have no or a very weak relationship (Vandeleur and Gill 2004). This study showed strong positive correlations between weed tolerance and suppression for each of the three weeds with *r* values ranging from 0.79 in ryegrass to 0.72 and 0.59 in oats and mustard (Figure 1). These results indicate that the wheat lines expressing high weed suppression will also provide greater levels of weed tolerance (yield maintenance), which is highly desirable for efforts to breed crop cultivars with improved competitive ability.

Conclusion

The CA of wheat measured in terms of weed seed production was highly stable across three weed species. This trend was reflected in significant (positive) correlations between each of the weeds. There was also a strong positive correlation between weed suppression and weed tolerance which is desirable for breeding efforts to develop cultivars with increased competitive ability as they must be able to compete with multiple weed species as weeds exist as mixed populations in field situations.

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