Perennial cereals: A novel source of feed for grazing livestock

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Abstract. Initial deployment of perennial cereal crops will likely be as a dual-purpose crop producing forage for livestock as well as grain. This study evaluated the biomass and grain production of 4 wheat × wheatgrass derivative experimental lines under 4 simulated grazing regimes; nil defoliation (D_0), defoliate once (D_1), defoliate twice (D_2) and defoliate twice followed by a simulated hay cut (D_3), and compared performance to a winter wheat, cv. EGA Wedgetail, and the perennial grass *Thinopyrum intermedium*. Increasing defoliation intensity significantly (P<0.001) lengthened the time to flowering for all lines. All experimental lines produced less biomass in the first year than EGA Wedgetail but more than *Th. intermedium* in the first spring. Grain yield from Wedgetail was significantly higher (P<0.001) than all other lines except in the D_3 treatment. As defoliation intensity increased, the comparative difference in grain yield between Wedgetail and the experimental entries decreased, with experimental lines OK 7211542 and 11955 exceeding the grain yield of EGA Wedgetail in the D_3 treatment. Cumulative biomass production of the experimental lines exceeded that of Wedgetail (P = 0.005), though the distribution of production, across seasons differed markedly. This paper discusses the opportunities perennial cereals may offer as a novel forage source in a mixed-farming context.

Keywords: Perennial wheat, *Triticeae* hybrids, *Thinopyrum* spp, dual-purpose crops, wheatgrass.

Introduction

Perennial cereal crops potentially offer more environmentally sustainable grain production into the future. Reductions in soil erosion, salinity and acidification, as well as reduced cost of production, are some of the proposed benefits from incorporating this novel technology (Glover and Reganold 2010). However the potential trade-off between perennial habit and reproductive effort in these species is likely to reduce grain yield. Adoption of these new cropping species will require production of green forage for livestock as well as grain, for profitable inclusion in a farming system (Bell *et al.* 2008; Reeling *et al.* 2012). As with other dual-purpose crops, the grazing potential of perennial cereals would be attractive for filling feed gaps and resting other pastures during the year. Very little has been published on the potential of perennial cereals for dual-purpose cropping and the impacts, if any, on persistence. Several experimental perennial cereal lines, previously identified as displaying good perennial habit (Hayes *et al.* 2012), were evaluated for their dry matter production, the response of grain yield and subsequent regrowth following defoliation.

Methods

The study was conducted at Cowra, in the mixed-cropping zone of NSW and was sown 19th April 2011. The entries included four wheat x wheatgrass derivatives (*Triticum* spp. x *Thinopyrum* spp: 11955, CPI-147235a (235a), CPI-1472280b (280b) & OK7211542 (OK 72)), the dual-purpose annual winter wheat cv. EGA Wedgetail (*Triticum aestivum*: Wedgetail) and the perennial grass *Thinopyrum intermedium* (055). Table 1 in Hayes *et al.* (2012) contains pedigree details of the entries. The experiment was a randomized split-plot design with six main-plots (entry) and four sub-plots (defoliation), with three replicates. Each main-plot consisted of four rows of each entry containing single plants spaced 10 cm apart over a distance of 1 m (10 plants per row). Each single 1 m row constituted a sub-plot that was defoliated by hand cutting to simulate four grazing intensities of nil (D_0; *i.e.*, grain-only), one defoliation (D_1), two defoliations (D_2) and two defoliations followed by a third defoliation to simulate a hay cut (D_3). The biomass from each treatment was removed, dried at 65°C in an oven and weighed to determine dry matter (DM) production. In each treatment, 10cm of above-ground biomass was retained after each defoliation event. The first defoliation occurred 57 days after sowing (DAS) with the second defoliation at 98 DAS. The hay cut, which was the third defoliation in D_3, occurred eight weeks after the second defoliation event (154 DAS). Flowering time of each entry was recorded. At maturity all material was harvested from the plots, leaving 10 cm of stubble above the ground. This was used to determine grain yield and harvest index. The survival of individual plants from each plot was recorded over the summer and into the autumn of 2012. Post-grain harvest biomass, if any, was cut in February 2012 and again in April 2012, and dried to determine DM production as per the biomass from the previous year.

All plots were fertilised with diammonium phosphate

Table 1. First season dry matter production (DM) measured in grams and year day of flowering (FD) for entries used in grazing experiment.

Entries	D_0		D_1		D_2		D_3	
	DM	FD	DM	FD	DM	FD	DM	FD
055	-	210	2.5	211	1.7	215	39.3	215
11955	-	186	41.3	186	26.6	188	225.5	195
235a	-	193	17.1	197	14.1	196	149.7	202
280b	-	185	19.2	185	13.3	189	110.6	196
OK 72	-	184	37.3	187	26.7	187	252.0	194
Wedgetail	-	156	100.4	161	70.1	163	315.6	186
lsd (P = 0.05)[a]			29.2	4.6				
lsd (P = 0.05)[b]			30.2	4.7				

[a] when comparing means within a defoliation treatment; [b] when comparing means with the same level of entry

Table 2. Total grain weight (GW) in grams and harvest index (HI) for entries used in defoliation experiment.

Entries	D_0		D_1		D_2		D_3	
	GW	HI	GW	HI	GW	HI	GW	HI
055	28.8	5.34	25.4	4.76	32.8	5.58	38.7	6.86
11955	188.1	24.97	171.7	24.05	142.7	22.52	84.5	18.79
235a	147.4	14.37	127.9	15.29	120.1	14.79	53.1	12.50
280b	90.6	16.42	70.4	14.36	68.4	16.28	44.6	14.16
OK 72	124.8	20.5	141.4	21.14	142.2	21.13	111.7	21.60
Wedgetail	461.2	47.85	320.8	47.59	384.0	46.36	35.3	37.06
lsd (P = 0.05)[a]			39.7	4.2				
lsd (P = 0.05)[b]			42.9	4.2				

[a] when comparing means within a defoliation treatment; [b] when comparing means with the same level of entry

Table 3. Comparison of spring dry matter production (DM) in grams with post-grain harvest DM (summer/autumn)for entries used in the experiment.

Entries	Spring 2011 DM				Post-harvest DM 2011/2012				Cumulative DM			
	D_0	D_1	D_2	D_3	D_0	D_1	D_2	D_3	D_0	D_1	D_2	D_3
055	-	3	2	39	239	213	299	230	239	215	301	269
11955	-	41	27	226	315	318	337	211	315	359	364	436
235a	-	17	14	150	145	50	111	52	145	67	125	201
280b	-	19	13	111	92	55	118	17	92	74	131	128
OK 72	-	37	27	252	149	216	205	67	149	254	231	319
Wedgetail	-	100	70	316	0	0	0	0	0	100	70	316
lsd (P = 0.05)[a]		100.2										
lsd (P = 0.05)[b]		89.2										

[a] when comparing means within a defoliation treatment; [b] when comparing means with the same level of entry

Table 4. Average number of plants remaining across defoliation treatments post-grain harvest from December 2011 through to April 2012

Entries		Assessment date			
		Dec 2011	Jan 2012	Feb 2012	April 2012
055		9	9	9	9
11955		10	10	10	8
235a		10	10	9	5
280b		10	10	7	4
OK 72		10	10	10	6
Wedgetail		0	0	0	0
lsd (P = 0.05)[a]	1.3				
lsd (P = 0.05)[b]	1.0				

[a] when comparing means within assessment date; [b] when comparing means with the same level of entry

at sowing at a rate equivalent to 100 kg/ha. A further application of urea was applied equivalent to 70 kg/ha to all plots, 119 DAS. Weed control of the experimental area was maintained via hand weeding. Data from the experiment were analysed using ANOVA (Genstat 11.1, VSN International, Ltd) and the 95% significance level was used.

Results

The annual wheat, Wedgetail, produced significantly (*P* <0.001) more dry matter (DM) in each defoliation treatment than any of the other entries tested (Table 1) in the first growing season of the experiment. The perennial hybrid wheat entries of 11955 and OK 72 had similar DM production during each defoliation and developed significantly more DM than the other two hybrids tested. The perennial grass 055 had the lowest DM production across all defoliation intensities applied. This was indicative of less vigorous growth of this entry in the first year.

Increasing defoliation intensity significantly (*P* <0.001) lengthened the flowering time of Wedgetail (Table 1). Flowering time was less influenced by the intermediate defoliation intensities in the other entries, except in the D_3 treatment, which delayed flowering compared to the nil treatment. Wedgetail had earlier flowering, while 055 was the last to flower of all the entries tested.

Wedgetail had the highest grain recovery (Table 2) in all defoliation treatments except at the highest intensity (D_3). There was better tiller development post defoliation by 11955 and OK 72 in this treatment, producing significantly (*P*<0.001) more grain than Wedgetail. There was also better post-defoliation recovery in 055, however this was not reflected in grain yield due to the lower grain size of this entry (data not shown). Wedgetail also had significantly (*P*<0.001) higher harvest index (HI) than the other entries tested, although this was substantially reduced by the D_3 treatment. HI was not significantly affected by defoliation in the other entries, except for 11955 which had reduced HI in the D_3 treatment compared to the other defoliation intensities.

All perennial entries showed significant post-sexual regrowth following grain harvest. The DM produced over the summer period (2011/2012) and subsequent autumn (to April 2012) is shown in Table 3. There was a significant increase (*P*<0.001) in DM from the perennial entries over this period of the experiment, compared to the previous spring production, although there was lower DM production in the D_3 treatment during this time. The cumulative DM for the D_0-D_2 treatments produced by the perennial entries, excluding 235a and 280b, was greater than the DM produced by Wedgetail in the spring of year 1 (*P*=0.005). The DM production from Wedgetail was greater or statistically similar to most entries in the D_3 treatment, compared to the cumulative DM totals from the other entries, excluding 11955. The perennial line 11955 had the highest cumulative DM total of all entries tested.

Defoliation intensity had no significant influence (*P* = 0.602) on plant survival post-grain harvest. There was a significant reduction (*P*<0.001) in the number of plants which survived from entry 280b by the Feb 2012 assessment date, with a continued decline in plant survival through to April 2012 for this entry (Table 4). There was also a significant decline in plant survival from Feb 2012 to April 2012 from entries 235a and OK 72. The perennial grass entry maintained its plant numbers throughout the assessment period.

Discussion

The use of dual-purpose cereals has been an important strategy for increasing the flexibility and profitability of mixed- farming enterprises in southern Australia. The ability of these crops to increase feed availability in winter, when dry matter production from pastures is low, and then recover to produce grain yield has been well documented (McMullen and Virgona 2009). For perennial cereals, their dual-purpose ability will also be important for profitable inclusion in a farming system. In annual crops, a large proportion of photosynthetic products and nutrient accumulation are diverted into grain production. In perennial species, there is a significant allocation of these resources into perenniating structures as well as grain development. Lower HI was observed among the perennial entries in the current study, suggestive of this reallocation of resources. A desktop study of whole-farm budgets has suggested that for perennial cereals to be economically viable, they would need to achieve grain yields at a minimum of 40% of annual wheat and offset the lower grain recovery by providing an extra 800 kg/ha of DM above the forage production of an annual crop (Bell *et al.* 2008).

In the current study the lower grain yield of the perennial hybrid entries was observed. Under no defoliation the yield of these entries was less than 40% of the annual wheat control Wedgetail. However, as defoliation intensity increased, the yields of most perennial entries exceeded 40% of the annual wheat, particularly in the D_3 grazing treatment. There was also variation among perennial entries for plant survival into the second growing season, with some entries showing higher rates of plant mortality than others. The grazing annual wheat cultivar used in the current study also produced greater levels of DM compared to the other entries under all defoliation intensities. However, post-sexual regrowth following grain harvest by the perennial entries allowed substantial DM production in the subsequent season. This exceeded the DM production from the annual wheat cultivar from the previous spring, particularly from entries 11955 and OK72. Vigorous autumn regrowth among other perennial cereals has also been observed (Jaikumar *et al.* 2012).There was also better DM production by the perennial grass entry during this period, compared to the previous spring, presumably due to its already established roots and crown. Cumulative biomass production across both spring and summer, in most defoliation treatments and perennial entries exceeded the DM produced by Wedgetail.

Conclusion

This study has shown that among the early generation of perennial wheat derivatives available, there is promise to develop dual-purpose crops. Although not commercially deployable, their grain yields and DM production approach the production benchmarks for perennial cereals as described by Bell *et al.* (2008). It is possible that with further selection and breeding, higher DM production and grain yields could be achieved. However, selection for improved grain yield will need to be tempered by the need to maximise plant longevity to ensure post year 1 production is maintained or improved. The effect of grazing on plant longevity and grain yield in the longer term still needs to be assessed.

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