

Yield components of reduced tillering wheat lines from the Yaruna multi-parent population

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Abstract

Reversing the trend of declining rates of wheat yield increase in Australia will require a substantial change in the genetic and management bases of production. Key genetic attributes may include reduced tillering and improved grain number/ear. In this paper yield components of plants from a bulk population of wheat (Yaruna multi-parent population = YaMPP) containing homozygous reduced tillering genotypes derived from a diverse 9 parent cross which included the very reduced tillering Uniculm 492 line are described. Yield components of main culms of individual homozygous plants grown in field plots at 100-150 plants/m² are often 1.2 to 4 times greater than free tillering varieties. Selected lines exhibiting the 'tin' gene when grown at standard crop densities have achieved HI values greater than 0.5, and grain numbers/ear over 60 and as high as 146. Many individual plants in YaMPP and the selected lines exhibit reduced tillering, large grain numbers per ear, large and often uniform grain size, very strong straw, and plant height between 60 and 100cm. Improvements in these components are necessary to increase yields in the dryland systems found in Australia, and a key challenge is to test the yield potentials of a broader range of reduced tillering genotypes under a diversity of environments.

Key words

Uniculm, ideotype, yield components, reduced tillering, 'tin'

Introduction

The reduction in rates of yield improvement in wheat in Australia have been characterised by a number of authors (eg. Lake, 2012; Fisher et al., 2012). Zhang et al, (2012) have indicated a strong need for either increased harvest index or increased grain number/m² as ways to increase yield in the high rainfall zone of Western Australia. However in dry seasons the high tillering of modern varieties which drives grain number/m² can impose a significant cost in wasted water use before grain filling starts. Reduced tillering lines in theory provide opportunities to use water more efficiently and so increase yield under terminal drought stress. In practice 'tin' genotypes have often not achieved this, and instead shown equal or reduced yield (Mitchell, et.al, 2012). In this paper I provide results for plants containing the 'tin' gene, developed in a segregating population using the 'B' model selection ideotype of Donald and Hamblin (1976), which may be useful as a source of genetic variability to increase yield components in dryland wheat.

Materials and Methods

The Yaruna Multi-Parent Population (YaMPP) was derived from a complex cross between 9 parents involving Miling, Egret, Gabo, Pitic 62 (occurs twice), Mexico 120, Ramona and Stewart (durum), with the final cross made in 1987 to Uniculm 492 (Atsom and Jacobs, 1977; Richards, 1988). The segregating population has been grown as a bulk in the medium rainfall wheat belt of Western Australia since 1993. In 2003 approximately 300 primary ears were selected at maturity from plants exhibiting unicum, biculm or triculm character as the sole determinant for selection. The seeds were bulked and continue to be grown and harvested as the primary YaMPP. In each year a compound starter fertiliser with nitrogen between 6 and 10kg/ha and phosphorus between 3 and 10 kg/ha is applied in the seeding operation.

Two assessments were made of the genetic material in 2014 – firstly of plants from the YaMPP bulk, and secondly of lines derived from single ear selections from YaMPP taken in 2012. Small plots were grown on a medium fertility red loam with a weak hardpan at about 40cm, and sown at a seed rate of 70kg/ha with a compound fertiliser that delivered 6kg/ha of nitrogen and 5kg/ha of phosphorus. The plots were sown in mid-June, harvested during December and January, and received 320mm growing season (April to October) rainfall. Final plant density ranged between 100 and 150 plants/m².

In the first assessment, three 2.5 metre lengths of row from the centre of a 5 row YaMPP plot were sampled. Individual culms exhibiting the largest ear size (main stem) from each of 17 plants/replicate were harvested, oven dried and measured for plant height, non-ear culm weight (SW), grain weight/ear (TGW), spikelet number/ear (SN) and grain number/ear (GN). The 1000 grain weight (1000GW), harvest index/culm (HI = TGW/SW+TGW+ chaff weight) and grain number/spikelet (Gr/Sp) were derived values. The remaining plant material from each replicate was threshed to provide a dry weight of grain. A yield estimate for YaMPP was calculated using the combined data sets from the individual plants and the bulk sample replicates. An additional 49 primary culms collected at random from unicum, biculm and triculm plants in the centre rows of other YaMPP plots provided a total of 100 ears for the population analysis. The full 100 culms were used in the correlation analysis of yield components.

In the second assessment detailed measurement of yield components was undertaken for the ‘tin’ line BCW2 (derived from YaMPP), identified as having high yield potential from small plot experiments in 2013. Six unicum, biculm, and triculm plants, and six plants with apparently higher stem number (4-5) were sampled and data from all culms collected (the higher stem number plants were found to be multiple seeds at a single point – data not presented). As a standard, 10 culms from plants of Magenta wheat grown at the same site and under similar conditions, and 10 culms from plants of Mace wheat from an adjacent commercial crop were analysed.

Four ‘tin’ lines selected from YaMPP in 2012, but which exhibited lower yields than BCW2 in small plots in 2013, were also grown in small field plots and some yield components measured. With the lines BCW3, BCW5, BCW6 and BCW7 eighteen culms were sampled.

Results

The YaMPP single culm selections are characterised by a diverse, but normally distributed range of yield component characteristics, many of which are strongly related to grain yield per ear (Table 1). Harvest index/culm is high in a number of selected plants (eg, plant 5, 55), but this is not necessarily associated with increases in other yield components. Some individual plants (Table 1) and the selected lines BCW2-7 show culm yield components much greater than conventional varieties (Table 2), and with values 1.2 to 4 times greater. There are strong positive correlations of spikelet number per ear, stem weight, 1000 grain weight, grains/spikelet and grains/ear to total grain weight/ear. Harvest index was negatively correlated with stem weight in this population and positively correlated with 1000 grain weight.

Table 1. Yield components of the main stem of 100 plants sampled from the YaMPP in 2014, of 7 ‘tin’ plants with the highest yield individual components (highlighted in bold), and the Yield Component (YC) correlations of the 100 plants.

	Plant Height (cm)	SpN	SW (g/stem)	TGW (g/ear)	1000 GW (g/1000)	HI	GN	Gr/Sp
Poptn Mean	75	20.30	3.84	3.45	44.4	0.47	78	3.8
Max.	110	30.00	8.29	6.50	57.00	0.58	146.00	5.6
Min.	58	13	1.22	0.38	14.6	0.16	14	0.7
Plant 4	110	22	3.52	2.8	42.6	0.44	71	3.2
Plant 24	76	30	5.95	5.72	40.4	0.49	146	4.9
Plant 43	77	27	8.29	6.11	50.6	0.42	129	4.8
Plant 17	87	26	7.32	6.5	48.8	0.47	130	5.0
Plant 5	83	21	3.68	5.1	57	0.58	91	4.3
Plant 55	77	17	2.36	3.24	50.6	0.58	64	3.8
Plant 45	81	21	7.31	5.21	53.8	0.42	117	5.6
YC corr.								
PH	-	0.13	0.42	0.41	0.35	-0.04	0.33	0.39
SpN		-	0.61	0.66	0.18	0.08	0.76	0.43
SW			-	0.84	0.48	-0.22	0.84	0.78
TGW				-	0.68	0.27	0.95	0.88
1000GW					-	0.4	0.45	0.52
HI						-	0.2	0.25
GN							-	0.9

For Correlation analysis $P < 0.05 = 0.196$, $P < 0.01 = 0.255$

While the plants within YaMPP are now essentially homozygous, the oligoculm BCW2 still showed plasticity for the ‘tin’ character with unicum, biculm and triculm plants present in the plots. The individual yield components per culm were largely stable for plants expressing 1, 2 or 3 tillers (Table 2). The five BCW lines also exhibited improved yield component values per culm over the free tillering varieties and similar to the Unicum 492 parent. When grain from BCW2 was sorted through different sieve sizes 89% of seed was greater than 2.8mm and only 0.1% below 2mm, while the mean value for the YaMPP replicates was 62%. Seed from an adjacent commercial crop of Mace wheat (R and B. Gentle) planted 3 weeks earlier and with higher nitrogen application achieved 30% of seed greater than 2.8mm (paddock yield just over 3t/ha).

Table 2. Yield components of BCW (*tin*) lines derived from YaMPP and free-tillering WA varieties in 2014 field or farmers plots, and the Unicum 492 source of reduced tillering germplasm (from literature)

Genetic material	SpN	SW (g/culm)	TGW (g/ear)	1000 GW (g/1000)	HI	GN	Gr/Sp
BCW2 (<i>tin</i>)							
- Unicum plant	20.8	2.8	4	48.5	0.51	84	4
- Biculm plant	19.0	2.3	3.4	47.1	0.52	71	3.7
- Triculm plant	19.9	2.6	3.4	44.7	0.48	76	3.8
BCW3 (<i>tin</i>) -		3.0	3.3	51.2	0.53	65	
BCW5 (<i>tin</i>)		2.4	3.3	50.8	0.58	64.5	
BCW6 (<i>tin</i>)		2.5	3.4	54.0	0.58	64	
BCW7 (<i>tin</i>)		1.9	2.9	51.0	0.60	57	
Mace - farmer	13.5	1.3	1.4	40.3	0.46	34	2.5
Magenta	12.9	1.0	1.3	40.0	0.48	33	2.6
Unicum 492 – from Atsom and Jacobs / <i>Richards</i> (1977/1988)	20.8	3.4	4.4	41.4	0.48	106, 64-85	5.1

The YaMPP bulk yield analysis produced a yield of 4.5t/ha compared to the 3.56t/ha site mean at the closest NVT trial site 5 km away (sown 3 weeks earlier on a similar soil type and with 90 kg N/ha applied during the growing season (NVT Trials - WMaA14YORK6).

Observation of the YaMPP over the last 5 years shows that it contains plants with a range of morphological and physiological characteristics. These include, but are not limited to, strong straw, large dark green leaves, reduced tillering, differing ear shape, large grain size, large grain number per ear, flowering time, grain filling efficiency (crease in-fill), grain shape, waxy leaves, and stay green character.

Discussion

The development of YaMPP and the use of the reduced tillering line Unicum 492 as a parent used a similar, though independent, approach to that reported by Indian plant breeders who have developed similar material – the Indian New Plant Type (Singh et al., 2001) and which has a reported yield increase of 20–30% over free tillering varieties. Australian germplasm with reduced tillering genes has focused on the use of isogenic lines to test hypotheses that reduced tillering has benefits in dryland production systems. Improved grain size and reduced screenings have both been found using this approach (Mitchell, et al 2012). The oligoculm line BCW2 expressed both increased grain weight and very large grains size with very low screenings, despite having nearly 25-30% of its ear weight as chaff, and strongly supports the hypothesis that reduced tillering is an advantage for reducing screenings under at least mild late season water stress.

The diversity of plant types with ‘tin’ characteristics present in the YaMPP material offers a new opportunity to explore the physiology of yield in a dryland environment with a short growing season. Many of the components identified as being necessary to lift yield above the current level in the higher rainfall zone (Zhang, et al, 2012) are present in plants from the YaMPP population, with grain number per ear being

particularly high in some ears when grown under commercial field densities. If ear number/ha can be maintained at or above the 250/m² target (125 plants/m² X mean 2 ears/plant) for these types, then substantial yield improvement would appear possible.

While fully replicated yield tests reduced tillering lines from YaMPP are currently underway, the bulk population yield of YaMPP from 2014 provides limited evidence that yield improvement should be possible. Mitchell et al (2013) found yield increases with reduced tillering lines under mild stress in the order of 11% compared to free tillering lines, although the isogenic lines in their experiments expressed low kernel weights. Using a potential yield estimation formula (Passioura and Angus, 2006) of kernel number/ha X kernel weight for BCW2 for a hypothetical ear number of 250/m², produces an estimated potential yield of 8.3t/ha – or a doubling of the best commercial yields reported by farmers in the York area of WA, and twice that from the Mitchell et al. (2013) experiments.

The genotypes with higher yield components which are necessary to increase yields in the dryland systems may include those with reduced tillering. These genotypes exist within Australia and the world, and a challenge is to test the potentials of a broader range of reduced tillering genotypes under a diversity of environments for improved yield and quality.

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