Comparing the yield of reduced tillering wheat genotypes at different sowing densities

Andrew Fletcher[1], Greg Rebetzke[2], Gary Ogden[3]

[1] CSIRO Agriculture and Food, Centre for Environment and Life Sciences, PMB 5, Wembley, WA, 6913, Andrew.L.Fletcher@csiro.au
[2] CSIRO Agriculture and Food, Black Mountain, GPO Box 1700, Canberra, ACT, 2601
[3] CSIRO Agriculture and Food, Centre for Environment and Life Sciences, PMB 5, Wembley, WA, 6913

Abstract
Reduced tillering wheat genotypes containing the tiller inhibition (*tin*) gene have been proposed as a way to reduce year-to-year variation in grain yield in Australia in dryland cropping regions. In extremely poor seasons, reduced tillering can lead to improved yield by limiting the crops investment in tillers that do not contribute to yield. However, in average or above average seasons reduced tillering can lead to a lower yield due to a reduction in fertile heads. This research tested whether increased seeding rate could offset this yield decrease. Seven genotypes including two commercial check varieties and near isogenic lines either with or without the *tin* gene were sown in two consecutive seasons in the low rainfall zone of WA. Crops were sown at 25, 50, 100, 200 and 300 plants/m². In both seasons yield potential, measured by the two commercial check varieties was ~2t/ha. Although emergence was poor in one season (~50%), the number of observed heads varied with density treatment and tillering capacities. Thus, the comparison between yields at similar head densities was valid. In the second season plant population was higher (85%). In both seasons, sowing density and genotype had a significant effect ($p<0.001$) on wheat yield but there was no interaction between them. Averaged across all genotypes and both seasons, genotypes with the *tin* gene yielded 62% less ($p<0.001$) than their free-tillering isogenic pairs. The lack of interaction with sowing density meant that increased sowing rates were unable to offset the yield reduction associated with the *tin* gene. This research challenged the ability of *tin* genotypes to stabilise yields by limiting yield loss at low yield levels. Furthermore, if fewer tillers in poor seasons is the objective then reducing plant population would appear a more cost effective option than using a genotype with the *tin* gene.

Key Words
Ear number, sowing density, *tin* gene, yield stability

Introduction
In the dryland cropping areas of Australia water is the limiting factor to yield (Turner and Asseng 2005). In Western Australia (WA) wheat yields are highly variable from season-to-season. This is a major management constraint as it can limit the farmer's ability to match inputs, such as fertiliser N, to yield potential. The industry requires genetic and management solutions to stabilise yields by increasing yields in low yielding seasons.

Tillering is an important phase for wheat crops. It provides a basis for the crop to expand leaf area and capture resources such as solar radiation. Fertile tiller number is the primary determinant of grain number per hectare which determined yield. However, in lower yielding seasons, wheat crops may produce excess (wasteful) tillers that are not required to achieve yield potential. Reducing the number of tillers per plant using the tiller inhibition (*tin*) gene (Richards 1988) has been proposed as a way to improve yield stability in these environments by reducing the investment in wasteful late tillers that do not contribute to yield (Mitchell *et al.* 2013). Reducing the number of infertile tillers would in theory increase yields in poor seasons. However, the trade-off would be that in higher rainfall years the lower number of tillers may lead to reduced grain numbers and lower yields (Houshmandfar *et al.* 2019) due to reduced plasticity to respond to better environments (Sadras and Rebetzke 2013). Breeders and farmers need to understand the yield *vs* yield stability trade-off with these genotypes.

It is possible that this yield penalty could be overcome by sowing a greater density of plants. As a rule of thumb, to obtain water limited yield potential wheat requires 1 head per m^2 per mm of growing season rainfallfree tillering genotypes due to increased grain number per spike. Therefore, to achieve the same yield less stem material would be required.

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The objectives of this research were to compare the yields of wheat genotypes containing the *tin* gene with free tillering genotypes; and compare the response to sowing density across genotypes containing the *tin* gene with free tillering genotypes. The hypotheses were 1) that genotypes containing the *tin* gene yield less than free-tillering genotypes at high yield potentials; 2) that the genotypes with the *tin* gene would be more sensitive to low plant populations; and 3) that the *tin* genotypes could produce similar yields with lower head densities.

Methods

Two experiments were planted in successive years (2017, 2018) in the eastern wheat belt of WA. In 2017 the site was at Moorine Rock (31.33°S, 119.15°E) (sown 09 May 2017) and in 2018 the site was at Muntadgin (31.72°S, 118.57°E) (sown 19 May 2018). Each experiment was a randomised complete block design with seven genotypes (including two commercial cultivars and five near isogenic lines (NILs) either with or without the *tin* gene (Table 1), and five sowing densities with three replications. One set of NILs (7770+ *tin* and 7770-*tin*) were Wyalkatchem-derived backcross lines. The other set of NILs were in a background of the cultivar Banks, and with either free tillering (Banks-*tin*), restricted tillering (Banks+*tin*), or double restricted tillering (Banks++*tin*). Target sowing densities were 25, 50, 100, 200 and 300 plants/m^2. These were adjusted to account for differences in seed size and germination between genotypes.

Table 1. Wheat genotypes used in the experiments.

Free tillering genotype	Restricted tillering pair	Double restricted tillering pair
	Commercial wheat cultivars	
Scepter		
Mace		
	Near isogenic lines	
7770 (-*tin*)	7770 (+*tin*)	
Banks (-*tin*)	Banks (+*tin*)	Banks (++*tin*)

Plot sizes were 4 m long and 1.5 m wide with inter-row spacing's of 25.4 cm (6 rows). Plots were sown using a cone-seeder and fertiliser, pesticides, fungicides and herbicides were applied so as not to limit growth and yield. Plots were harvested at physiological maturity using a small plot header and yields are reported corrected for harvested moisture content (~12%). Prior to harvesting a 0.5m^2 quadrat was harvested to count the number of spikes.

Each experiment was analysed separately using ANOVA in Genstat version 19.1 (VSN-International 2017). The effect of the *tin* gene on yield and the interaction with sowing density was tested using orthogonal contrasts. Means separation used Fishers protected LSD with α=0.05.

Results

Growing season rainfall (Apr-Oct) was 135mm in 2017 and 218mm in 2018. This was sufficient to achieve a mean yield of the commercial cultivars of 2.08 t/ha in 2017 (Figure 1a) and 2.05 t/ha in 2018 (Figure 2a). Both sowing density and genotype had a significant effect ($p<0.001$) on wheat yield in 2017 but there was no interaction between them. The genotypes with the *tin* gene consistently yielded less ($p<0.001$) than their free tillering versions (Figure 1). Averaged across sowing densities the yield of the restricted tillering 7770 (+*tin*) genotype (0.84t/ha) was approximately half that of the free tillering 7770 (-*tin*) (1.62 t/ha) (Figure 1b). Similarly, the yield of the Banks restricted tillering (+*tin*) (0.80 t/ha) and double restricted tillering (++*tin*) (0.75 t/ha) genotypes were much less than the free tillering banks genotype (-*tin*) (2.03 t/ha) (Figure 1c). There was a consistent response of yield to target sowing density. Averaged across all genotypes 90% of maximum yield was achieved with 69 plants/m^2. The large difference in yield between the reduced tillering and free tillering genotypes and the consistent response to plant density meant that no matter the sown plant population the reduced tillering line could never reach the yield of the free tillering line. Visually, plant establishment was poor in 2017 (~50%). Unfortunately, this was not measured directly. However, the number of heads at harvest was in line with the applied treatments. (i.e. the treatments with the highest head populations were achieved with the higher plant densities and with the free tillering lines). Thus, although the poor establishment impacted overall yield potential it did not influence the relative differences between treatments. Furthermore, although establishment was poor there was still a sufficient head density at harvest to achieve a yield of approximately 2t/ha of both commercial cultivars for all but the lowest plant population.

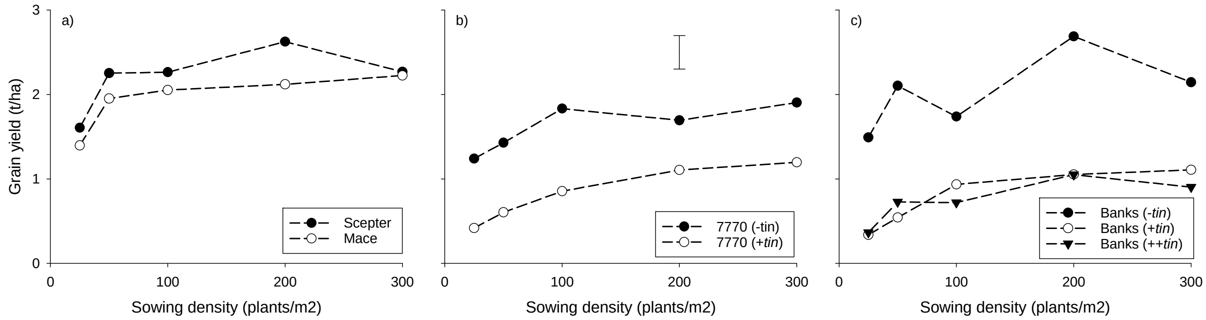

Figure 1. Grain yield of commercial wheat cultivars (a), 7770 NIL's (b), and Banks NIL's (c) either with or without the *tin* gene at varying sowing densities in 2018. Error bar is 1LSD (α=0.05) for comparing between varieties at the same sowing density.

Plant establishment was much better in 2018 with a mean emergence of 82%. There were no differences in emergence rate between varieties (p=0.115) and no interaction with target density. The proportion of sown seeds emerging was greater at lower target sowing densities (p<0.001). Emergence rates were 99.4%, 86.6, 84.5, 71.4 and 67.3% for target sowing densities of 25, 50, 100, 200 and 300 plants/m^2 respectively. Again, both target sowing density and genotype had a significant impact (p<0.001) on yield but there was no interaction between them. The genotypes with the *tin* gene consistently yielded less (p<0.001) than their free tillering versions. Averaged across sowing densities the yield of the restricted tillering 7770 (+*tin*) genotype (1.46) was 0.43 t/ha less than the free tillering 7770 (-*tin*) (1.89 t/ha). Similarly, the yield of the Banks restricted tillering (+*tin*) (1.98 t/ha) and double restricted tillering (++*tin*) (1.66 t/ha) genotypes were 0.21 and 0.53 t/ha less than the free tillering banks genotype (-*tin*) (2.19 t/ha). The smaller yield difference between the restricted tillering and free tillering lines in 2018 was likely due to the greater number of established plants. There was a consistent response of yield to sowing density in 2018. Averaged across all genotypes, 90% of maximum yield was achieved with 62 plants/m^2. The large difference in yield between the reduced tillering and free tillering genotypes and the consistent response to plant density meant that no matter the plant population the reduced tillering line never reached the yield of the free tillering line.

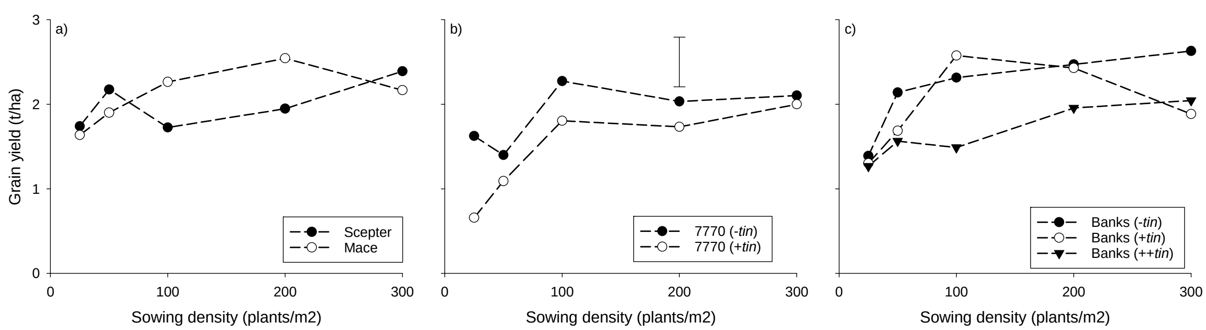

Figure 2. Grain yield of commercial wheat cultivars (a), 7770 NIL's (b), and Banks NIL's (c) either with or without the *tin* gene at varying sowing densities in 2018. Error bar is 1LSD (α=0.05) for comparing between varieties at the same sowing density.

For each year experiment there was a consistent relationship between the density of heads and yield. In 2017 each head produced on average 1.27 g of grain (Figure 3a). This meant that each 1t/ha of grain required ~80 heads/m^2. In 2018 each head produced on average 0.8 g of grain (Figure 3b). This meant that each 1t/ha of grain required ~115 heads/m^2. This highlighted that there was limited capacity for the *tin* lines to compensate for the low number of heads per m^2 by increasing yield per head. However, in 2017 there were differences in this line between genotypes. With the free tillering genotypes tending to have greater yields for a given number of heads per m^2. This implied that the *tin* gene was restricting yield by some other additional factor. In 2018 the only difference between genotypes was that the commercial cultivar 'Scepter' tend to produce greater yields for a given number of heads per m^2. This implies that in 2017 there was some other additional factor limiting the yields of the restricted tillering genotypes.

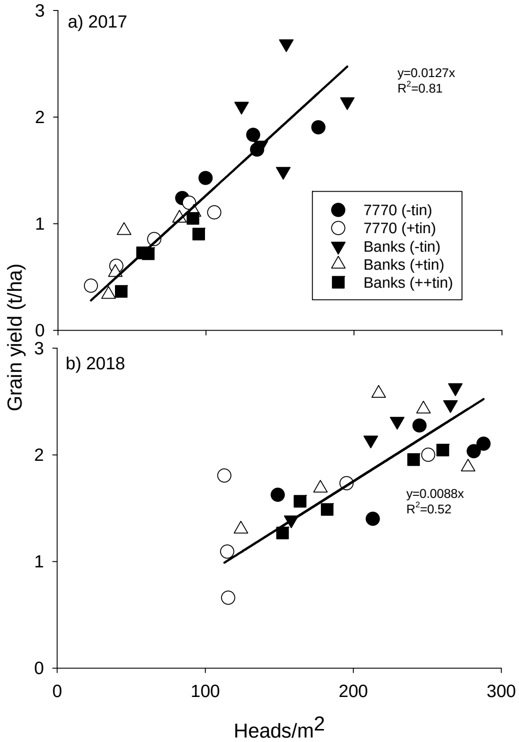

Figure 3. Relationship between head counts and grain yield of near isogenic wheat lines either with or without the *tin* gene for (a) 2017 and (b) 2018.

Averaged across all genotypes and both experiments the reduced tillering genotypes containing the *tin* gene yielded 62% of the corresponding free tillering genotype (data not shown). This appeared to be consistent across the two trials and there was no evidence of the *tin* genotypes yielding more at low yields. However, these experiments only had two contrasting environments and none were yielding less than 0.5 t/ha.

Conclusion

There was no interaction between target density and the presence of the *tin* gene on wheat yield in the low rainfall zone of WA. Increased plant density was not a viable solution to counteract the yield penalty associated with the *tin* gene. This research has challenged the utility of the *tin* gene to stabilise yields in this environment, and contrasts with yield benefit with *tin* elsewhere (Mitchell *et al.* 2013; Moeller and Rebetzke 2017). Furthermore, if fewer tillers in poor seasons is the objective then reducing density of free-tillering lines will be a far more cost effective option than using a genotype with the *tin* gene.

References

GRDC, 2015. Grownotes - Wheat. Grains Research and Development Corportation, 372.

Houshmandfar, A, Rebetzke, GJ, Lawes, R, Tausz, M (2019) Grain yield responsiveness to water supply in near-isogenic reduced-tillering wheat lines – An engineered crop trait near its upper limit. *European Journal of Agronomy* **102**, 33-38.

Mitchell, JH, Rebetzke, GJ, Chapman, SC, Fukai, S (2013) Evaluation of reduced-tillering (tin) wheat lines in managed, terminal water deficit environments. *Journal of Experimental Botany* **64**, 3439-3451.

Moeller, C, Rebetzke, G (2017) Performance of spring wheat lines near-isogenic for the reduced-tillering 'tin' trait across a wide range of water-stress environment-types. *Field Crops Research* **200**, 98-113.

Richards, R (1988) A tiller inhibitor gene in wheat and its effect on plant growth %J Australian Journal of Agricultural Research. **39**, 749-757.

Sadras, VO, Rebetzke, GJ (2013) Plasticity of wheat grain yield is associated with plasticity of ear number %J Crop and Pasture Science. **64**, 234-243.

Turner, NC, Asseng, S (2005) Productivity, sustainability, and rainfall-use efficiency in Australian rainfed Mediterranean agricultural systems. *Australian Journal of Agricultural Research* **56**, 1123-1136.

Zhang, H, Turner, NC, Simpson, N, Poole, ML (2010) Growing-season rainfall, ear number and the water-limited potential yield of wheat in south-western Australia. Crop and Pasture Science. **61**, 296-303.