Agronomic responses of newly bred short season peanut cultivars in a variable subtropical environment

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Abstract
Peanut production in subtropical Australia has been steadily declining due to increased climatic variability and change, leading to significant supply-demand gaps. Shorter season cultivars are being released to minimise the impact of climate variability and change. The agronomic responses of these new cultivars, however, are not known. We evaluated recently bred short-season cultivars at 5 to 20 plants/m^2 plant populations, 45 and 90 cm row spacings and with and without irrigation on a Ferrosol at Kingaroy during 2014-20. Pod yields were 2.6 to 7.8 t/ha. The pod yield response to planting density and row spacing was much smaller than soil water and cultivar differences, with 'Taabinga' being the best yielding cultivar. The results suggest that short season high yielding cultivars like 'Taabinga' can promote increased production of peanuts in rainfed production areas.

Keywords
Arachis hypogaea L., plant population, pod yield, row spacing, irrigation.

Introduction
The consumption of peanuts in Australia stands at 50,000 MT annually, whereas local production can barely meet around 40% of this requirement. The gap between demand and supply of peanut has been steadily increasing due to a decrease in production in the dryland region due to increased climatic variability and change since the 1980s (Meinke et al. 1996). This has also led to an increase in instances of aflatoxin contamination (Chauhan et al. 2010). To address these challenges the Australian peanut industry has placed considerable emphasis on breeding new generation early maturing (100 - 135 days) cultivars (Wright and Hansen 1997). Since 2006 four early maturing cultivars, including 'Walter' (in 2006), 'Tingoora' (in 2010), 'Redvale' (in 2013), and 'Taabinga' (in 2017) have been released. However, their adoption has been limited to a few growers as they cannot realise the same pod yields that full-season peanuts can achieve when planted in October or November and achieve high pod yields in good years.

As with other crops, the development of specific agronomy of these new early maturity peanuts has lagged their release. Growers are likely unable to exploit their full potential due to the lack of appropriate agronomy to optimise their potential. Therefore, the objective of this study was to collect basic agronomic information for newly developed early maturing cultivars on comparative responsiveness to plant population, row spacing, irrigation and the extent of seasonal pod yield variation. Sowing dates were generally based on minimum rain to trigger planting.

Methods
Cultural and treatment details

Field trials were conducted on Ferrosols of about 120 mm plant available water holding capacity from 2014 to 2020 at the DAF's Kingaroy Research Facility at Kingaroy, Queensland, Australia (26.55 °S and 151.85 °E). The details of the dates of planting, harvesting and treatments and design used are summarised in Table 1. All trials were laid in a split plot or randomised block design with three to five replications. We recorded pod yields at maturity after they were sufficiently sundried. Water use efficiency was computed by dividing pod yield by water use during the growing period. Data collected were analysed using linear mixed models in GENSTAT (VSN International) statistical program. A 5% significance level was used for all tests.

Results
Weather and average pod yield across seasons

The amount of rainfall received in different seasons varied from 351 to 449 mm (cv % = 23). The starting soil profile moisture generally varies from full to 1/3rd full in different years. The average rainfed pod yields varied from 2.6 to 7.8 t/ha (cv % = 32) and showed an increasing trend over seasons. In the highest yielding 2019-20 season, total rainfall was > 430 mm, but only 30 mm was received during the first 55 days (Fig. 1). Across seasons, the relationship of pod yield with rainfall was not significant. However, the relationship of cumulative growing degree days (GDD) at harvest with pod yield was significantly positive, with GDD accounting for about 79 % variation in pod yield across seasons (Fig. 1b).

Table 1. Time of sowing and treatment details of different peanut trials conducted at from 2014 to 2020 seasons.

Season	Date of sowing	Date of maturity	Treatments: Plants/m^2	Cultivar	Rows (cm)	Irrigation
2014-15	9 Dec.	27 Apr.	5, 10, 15, 20	Tin, Red, Taab	90	nil
2015-16	7 Dec.	21 Apr.	5, 10, 15, 20	Tin, Red, Taab	90	nil
2016-17[a]	13 Dec.	2 May	10, 15, 20	P20, P52, Taab	45, 90	nil
2017-18	7 Dec.	14 May	10, 15, 20, 25	Wal, Red, Taab	90	Rainfed, Irrig.
2018-19	10 Jan.	31 May	15	Red, Taab	90	Rainfed, Irrig.
2019-20	22 Nov.	23 Apr.,11 May	15	Taab, Alloway, Kairi, Fisher, Holt	90	Rainfed, Irrig.

Cultivar names are: Mid = Middleton, Fis = Fisher, Kai = 'Kairi', Tin = 'Tingoora', Red = Redvale, Taab = 'Taabinga'; Wal = Walter. [a]Experiment laid in a randomised block design, other experiments were planted in split plot design.

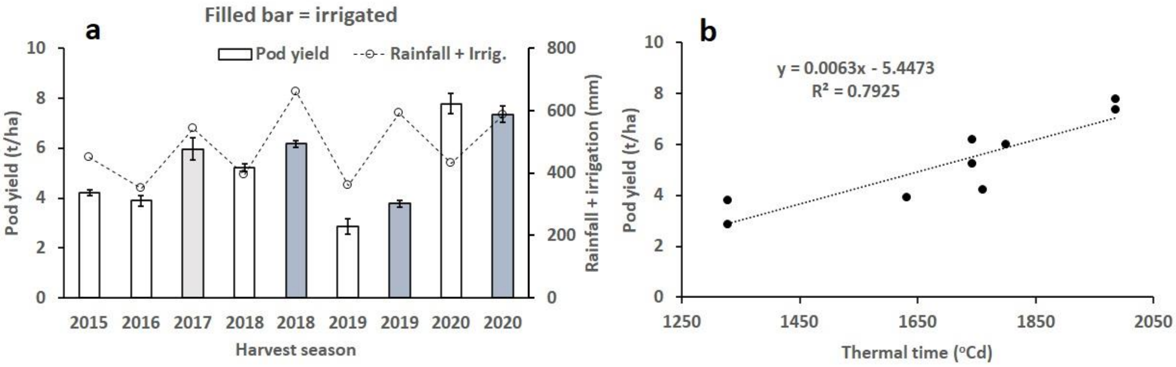

Figure 1. Pod yields of short-season 'Taabinga' from the 2014-15 to 2019-20 seasons and rainfall + irrigation in the respective seasons(a) and relationship of pod yield to cumulative thermal time at harvest (*p* <0.05) of 'Taabinga'. The shaded bars in (a) represent the average pod yield in the irrigated treatment and open bar, rainfed treatment. There was lifesaving irrigation given in 2017 to an otherwise rainfed crop. The error bars in a) are standard errors of means based on 3 to 5 replications.

Response to plant population

As in the past studies on peanut in the current study region, the effect of plant population was significant only in the 2014-15 season when pod yield at 5 plants/m^2 plant population was significantly less than at 10, 15, and 20 plants/m^2 (Fig. 2). There was no difference in pod yield from 10 to 20 plants/m^2. Full season peanuts are commonly grown at 10 to 15 plants/m^2. The plant population x cultivar interaction was not significant in any season.

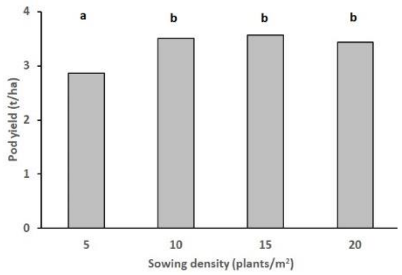

Figure 2. The effect of plant population pod yield in 2014-15. Pod yields with the same letters were not significantly different. LSD was 0.40 (P = 0.05).

Response to row spacing

Pod yields did not differ significantly when peanuts were grown on 45 cm or 90 cm row spacing in one season, nor was the interaction of row spacing with cultivar significant (results not shown).

Response to irrigation

The irrigation x cultivar interaction was highly significant for pod yield in 2017-18 but not in 2018-19 and 2019-20. In 2017-18, pod yields of three early maturing cultivars, ‘Walter’, ‘Redvale’ and ‘Taabinga’ were similar under rainfed conditions but differed significantly under irrigated conditions (Fig. 3a). Water use efficiency ranged from 6.9 to 10.3 kg/ha/mm and the cultivar x irrigation interaction was significant with ‘Taabinga’ showing higher water use efficiency under rainfed conditions in the same experiment (Fig. 3b). In 2018-19, neither irrigation nor cultivar effect was significant (results not shown).

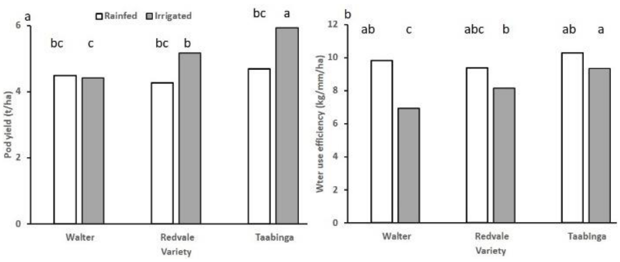

Figure 3. A comparison of pod yield (a) and water use efficiency (b) of early maturing peanut cultivars in 2017-18. Treatments with the same letters were not significantly different. Average LSD values 0.78 t/ha and 2.0 kg/mm/ha respectively. Open bars rainfed and solid bars irrigated.

Cultivar differences

Cultivar differences in pod yields were significant in three out of the six seasons. Interactions of cultivar and plant population or row spacing were not observed in any season. Overall, ‘Taabinga’ was the highest yielding cultivar. In 2019-20 ‘Taabinga’ gave pod yield of up to 7.8t/ha under rainfed conditions, which was like full season cultivar Holt, Fisher, Alloway and Kairi (Fig. 4).

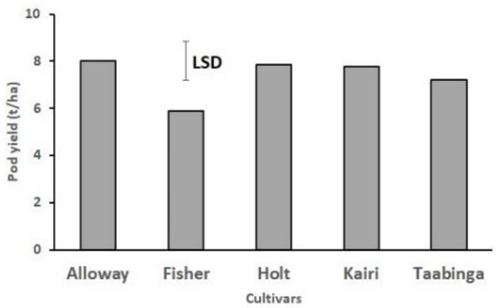

Figure 4. Mean pod yield of five peanut cultivars grown with and without irrigation in 2019-20. LSD = Least Significant Difference (P = 0.05).

Discussion

The lack of a significant response to plant population in the range of 10 to 25 plants/m^2 and 45 and 90 cm row spacings suggests peanuts are plastic and that these agronomic factors may not be the reason for low pod yield potential and variability observed. Erratic rainfall distribution rather than its total amount seems to contribute to much of the pod yield variability of early maturity peanuts. In experiments spread over six seasons of this study, the coefficient of variation in seasonal pod yield of Taabinga was 32%, which was higher than the variability in rainfall plus irrigation amounts for the comparable period (Fig. 1). Rainfall during the reproductive period is likely to be more critical for reliable production than during early growth stages when the crop seems better able to use stored soil water. More rain in the early part of the season may be counterproductive as it may lead to the development of a bigger canopy which may increase the early-season water use and increase the risk of drought stress later in the season if adequate rains are not received.

Indeed, in the 2019-20 season, when there was less than 30 mm of rainfall during the first eight weeks of growth, but 400 mm rainfall after that, rainfed pod yield achieved by the early maturity cultivar Taabinga was 7.8 t/ha (Fig. 1). The soil did not have much stored moisture before sowing, and hence pre-sowing irrigation was given to establish the crop. This was the highest pod yield recorded from any early maturing cultivar and perhaps is highest among other crop legumes of comparable maturity. Pod yield in this season was also comparable to full season peanut cultivars such as Holt, Kairi, Fisher and Alloway in the same experiment. Cultivar ‘Taabinga’ apparently was better able to exploit rainfall and it responded better to irrigation when rainfall during reproductive period was less (e.g., in 2016-17). ‘Taabinga’ achieved a respectable water use efficiency of around 10 kg/ha/mm of water use, which was possibly because it was able to extend its growing period in favourable seasons (as in 2014-15, 2016-17 and 2019-20). ‘More such opportunistic cultivars need to be bred to take advantage of rainfall in good seasons.

Our results suggest that some growers’ reluctance to use short-season cultivars, which seems to stem from the perceived inability of such cultivars to make use of rainfall in good rainfall seasons, may reflect an over cautious approach. In our experiment in the 2019-20 season, when very high pod yields were achieved, we had established the crop with pre-sowing irrigation. Most dryland growers in the region were unable to do likewise and hence missed out on good rain later in the season and achieve high pod yields as we did. Thus, more research on peanut establishment under limiting moisture conditions may be an important research objective to improve the adoption of early maturing peanuts.

Conclusion

The Australian peanut industry is trying to address the twin challenges of climatic variability and change in major peanut production regions by introducing earlier maturing cultivars and developing cultivar-specific agronomy. These cultivars can escape terminal droughts. Over six seasons there was, however, appreciable variation in pod yield and a significant portion of this variation could be accounted by variation in growing degree days to harvest. Cultivar ‘Taabinga’ was generally the highest yielding cultivar exhibiting appreciable phenological plasticity by maturing earliest in terminal drought situation and taking longer to mature when there was no stress helping it achieve rainfed pod yields of up to 7.8 t/ha, which were comparable to full season peanuts. These results provide a clue that enhancement of phenological plasticity of early maturing cultivars may be desirable to achieve good pod yields in dry and wet seasons.

Acknowledgements

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