Adaptations for growing wheat in a drying climate

Summary
This scholarship supported Hayden Sprigg’s research in Western Australia’s (WA) eastern wheatbelt. Field work was carried out using rain-out shelters and irrigation facilities at the Department of Agriculture and Food WA’s (DAFWA) Merredin Research Station (MRS) (2008 and 2009). Modelling was completed in 2010 and the thesis submitted in July 2011.

The research measured wheat yield in relation to: a) rainfall distribution - high versus low growing season rainfall (GSR) with the same annual rainfall; b) variety; and c) management. The distribution of rainfall had the greatest (but inconsistent) effect on yield, followed by management (row spacing). Variety had little influence. Modelling with the Agricultural Production Systems simulator (APSIM) confirmed these responses and developed yield projections for the future.

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Conclusions

This scholarship provided support for Hayden Sprigg to undertake a PhD program, based at Curtin University's Muresk campus. Experimental work was completed mainly at the DAFWA Research Station at Merredin.

The thesis examined the implications of possible change in the distribution of rainfall in the eastern wheatbelt of WA ie. a shift from winter dominant rainfall to a pattern where a higher proportion of rain falls in summer. WA wheat crops traditionally grow on winter (seasonal) rainfall and make less use of out of season rainfall (compared with crops in northern Australia). A shift to a different rainfall distribution pattern in WA has implications for crop management systems and varietal choice to effectively store and use out of season rainfall.

The experimental program studied the influence of environmental, management and genetic factors on the response of wheat to rainfall. Of these, 'environment' was defined by different distributions of the same annual total rainfall - one regime being summer dominant and the other, winter dominant. Rainfall was controlled by rain-out shelters, which either protected the area from natural rainfall or allowed irrigation 'rainfall' to be applied. ‘Management’ investigated two row spacings (23 cm vs 60 cm), as wide row spacings are increasingly used in low rainfall environments to maintain yield in dry seasons. ‘Genotype’ was tested by using five varieties in 2008 and two in 2009 to determine if different genetic backgrounds provided any insight into future patterns of crop response to change in rainfall.

In summary, the timing of rainfall and the efficiency of storage and use of this water are crucial to optimise yield in dry seasons. However, highest yields were obtained from growing season rainfall in 2008 but from out of season rainfall in 2009. Reasons for this difference relate to management problems in 2008, which were overcome for the 2009 season. In the short term, however, it appears that growers can maximise yields by retaining the current row spacing of 23 cm, rather than adopting the wider spacing (60 cm) and that early application of nitrogen (N) is likely to be more reliable than later application. Selection of variety, in the short term, seems to offer relatively little yield benefit. However, grower experience in selection of varieties will continue to be important in relation to yield and quality, disease resistance and farming system.

The thesis provides indications to wheat breeders about traits that demonstrate stability under a range of stresses in low rainfall systems and discusses scope to develop wheat genotypes that are better suited to wide row spacings. Modelling results, however, confirm that wheat yields and economic returns are likely to fall under climate change scenarios to 2030. The ‘pessimistic’ scenario used in this study predicted major declines in yield and profitability without adaptation to a hotter and drier climate. The study confirmed the need for additional research to explore the impact of the interacting changes in CO₂, temperature (including frost), rainfall and evaporation on crop production in low rainfall areas.

Papers to promote the findings of the thesis to a scientific audience are planned. It is anticipated further presentations to Perth and regional Crop Updates in WA and to other grower and research forums will continue in the future.
Outcomes

The original outcome in the scholarship project schedule was defined as:

“A greater understanding of the interactions between genetic factors and seeding technologies that have the potential to increase wheat yields in drought seasons. The project will evaluate these genetics and technologies and conduct economic modelling to determine the effect on the farm business over time”.

The project compared two contrasting rainfall distributions within the same annual total rainfall ie. summer dominant and growing season (or winter dominant). These rainfall regimes were applied across several varieties and management options. The summer dominant rainfall treatment represented the predicted change in rainfall distribution under climate change scenarios for the WA eastern wheatbelt.

Economic benefits:

Economic benefits (ie. optimising production in a changing climate) will follow by ensuring that out of season rainfall is captured and stored efficiently and by choosing appropriate combinations of variety and agronomic management to make efficient use of stored water in a dry growing season. In this study, however, choice of variety appeared to have little impact on yield - nor did the study demonstrate any benefit from moving to wider row spacings (usually thought to benefit yield in dry seasons). In the long term, genetic improvements using specific traits to increase yield under dry conditions may deliver greater benefits to growers.

Environmental benefits:

If climate change predictions are correct and there is an increase in the proportion of annual rainfall in summer, there is a particular need to store and use that water efficiently The efficient storage and subsequent use of rainfall *in situ* will minimise the risk of ground water re-charge, reduce loss of rainfall through surface run-off and limit growth of summer weeds that waste water. Project findings will encourage the development of sustainable cropping practices that match rainfall and the productive potential of farmland.

Social benefits:

More reliable cropping in years of uncertain and lower rainfall will stabilise incomes from year to year and optimise returns within a year. This will provide greater financial security for individual farm businesses and increase the likelihood of healthy communities in rural areas. Nonetheless, the project predicted major changes in yields and economic returns which will threaten the viability of farming enterprises in the low rainfall eastern wheatbelt of WA - if current predictions of the climate in 2030 are correct.

Achievements/Benefits

Project GRS127 provided financial support to Hayden Sprigg from March 2007 to March 2010 to undertake research into ‘Adaptations for growing wheat in a drying climate’. In 2007, preliminary field work was carried out on the Muresk farm to familiarise Hayden with phenological development of wheat in relation to row spacing. A substantial literature review was started and planning for field work in the following seasons was completed.

Field work began at Merredin in 2008. The move to Merredin from Muresk was stimulated by: a) the need to work in a consistently drier climate which more closely reflected the rainfall and temperatures expected in the eastern wheatbelt of WA; and b) the availability of rain-out shelter facilities on the DAFWA Merredin Research Station (MRS) to allow different rainfall distributions to be applied in the same growing environment under realistic field conditions. In early 2010, Hayden spent ten days with the APSIM group in Toowoomba, Queensland (QLD), and discussed how to adapt and apply the row spacing routine (written for sorghum in the northern region) to wheat crops grown in southern Australia.

The experimental program looked at the influence of environmental, management and genetic factors on the response of wheat to rainfall. Of these, ‘environment’ was defined by two distributions of the same annual total rainfall - one regime being summer dominant and the other winter dominant. This reflected the anticipated change in rainfall distribution under climate change in the eastern wheatbelt of WA. Rainfall was controlled by rain-out shelters, which either protected the area from natural rainfall or allowed irrigation ‘rainfall’ to be applied. ‘Management’ was defined by two row spacings (23 cm vs 60
cm), as wide row spacings are increasingly used in low rainfall environments as a conservative strategy to maintain yield in dry seasons. 'Genotype' was tested by using a range of varieties (five in 2008 and two in 2009) to determine if different combinations of traits provided significant benefits. Total rainfall in both years was about 300 mm and rainfall had the biggest effect on grain yield in both years. In 2008, the growing season rainfall (GSR) treatment, growing season days (GSD), resulted in grain yields (1.80 tonnes/hectare) which were significantly higher than for summer dominant rainfall (out of season days (OSD) - 0.64 t/ha). Averaged across varieties, crops grown in the narrow row spacing outyielded those at the wide row spacing (1.41 t/ha vs 1.03 t/ha). Yields of the varieties (Halberd, Silverstar, Silverstar tin, Westonia and Wyalkatchem) did not differ significantly, although the ways in which each variety built yield varied considerably. There was also some evidence of interaction between variety and row spacing.

In 2009, only two of the original varieties were grown (Silverstar and Wyalkatchem) and an additional management treatment was imposed to look at the effect of timing of nitrogen application. Rainfall distribution, again, had the biggest influence on yield, but this time crops grown on GSD rainfall yielded less (1.36 t/ha) than those grown on out of season rainfall (1.72 t/ha). Crops on narrow rows again yielded significantly more than on the wide row spacing. Early (tillering) application of nitrogen had a greater effect on yield than later (stem elongation) application and there was, again, no effect of variety.

The contrasting effects of rainfall were unexpected. Preliminary modelling work was unable to replicate the yield results from the 2008 trial, which suggests that: a) not all the rainfall 'applied' through irrigation in summer for the OSD regime was stored effectively, and b) some damage to plants in the OSD treatment by glyphosate (used to control resistant ryegrass in the wetter plots) was more significant than first thought. In 2009, modelled yields were consistent with experimental results. In this second year, the summer irrigation to create the OSD treatment was applied at a lower rate over a longer period. On this poorly structured clay soil, it is likely to have increased moisture infiltration and storage and subsequent availability for crop growth and yield.

While all varieties suffered a yield penalty when grown at the wider row spacing in these trials, there was an interaction between variety and row spacing. Silverstar suffered more than other varieties. The two WA varieties, Westonia and Wyalkatchem, showed the smallest depression in yield at the wider row spacing. A full analysis of patterns of dry matter accumulation and water use led to a model for wheat genotypes better suited to wide rows - to allow growers to exploit the practical advantages of wide rows while minimising the disadvantages.

In the short term, however, it appears that growers can maximise yields by retaining the current row spacing of 23 cm, rather than adopting a wider spacing (60 cm), and that early application of nitrogen is likely to be more reliable than later application when N is at risk of limited availability in drying conditions. Selection of variety, in the short term, seems to offer relatively little benefit in grain yield - other than to fit grower experience with grain yield and quality, disease resistance and farming system.

Modelling (using APSIM) examined the impact of known changes in rainfall since 1975 for several locations in the low rainfall eastern wheatbelt of WA. This demonstrated a decline in yield from the northern and central locations, but lesser impact further south. Modelling 'optimistic' and 'pessimistic' future climates to 2030, however, showed that yields declined under both scenarios and at all locations. The 'pessimistic' projection suggested major losses of productivity and profitability (using 2010 data for grain prices and inputs) in this marginal cropping environment.

Papers to promote the findings of the thesis to a scientific audience will follow and presentations to Perth and regional Crop Updates in WA and to other grower and research forums are expected to continue.

Hayden presented interim findings of his research to grower audiences at a Regional Crop Update forum at Kellerberrin (February 2009) and to the main Merredin Field day (October 2009). He also presented his results to a national Workshop on ‘Wheat Production in the Western Region in Water Limited (drought-prone) Environments - where to next?’ in Perth in 2008. Hayden applied for and secured a position at the "Theo Murphy High Flyers Think Tank 09" titled 'Agricultural Productivity and Climate Change', run by the Australian Academy of Science in Melbourne in 2009.

This project has provided a great opportunity for a student to undertake research that is of benefit to the Australian grains industry and to meet researchers and industry personnel involved in the study of adaptation of wheat to drier climates.

Other research
There is much ongoing research to explore adaptation strategies for change in the amount and distribution of rainfall in future years. This requires work into varieties, adaptive traits, response to changes in temperature (including frost incidence and severity) and CO\textsubscript{2} - as well as rainfall, crop management systems and rotations and the interactions between these components. This research is particularly relevant in low rainfall environments where economic returns in dry years can be very low.

Field based projects (such as GRS127) can explore the response of current varieties (and advanced lines) to changes in rainfall distribution and amount and the effects of a small number of management options in relation to rainfall across a limited number of seasons. In this project, modelling allowed extrapolation of 2009 findings beyond the limits of time and season and developed general responses for a range of rainfall and row spacing scenarios. However, further research (and modelling) is needed and must use new varieties and advanced lines tested against the changes in CO\textsubscript{2} and temperature that are likely to be associated with changes in rainfall amount and distribution. This new material will incorporate traits with potential to maintain or increase crop performance in hotter, drier conditions and these must also be evaluated against the impacts of a range of crop management strategies. Research to tackle these problems will require either new field based facilities so that rainfall, CO\textsubscript{2} and temperature can be manipulated in a 'natural' field environment of temperature and radiation, or will need the development of sophisticated controlled environment facilities to mimic realistic field environments.

This project provides a platform to continue field based studies of the interactions between genotype and management in a changing rainfall and climatic environment.

Additional information

1. Sprigg H. Adaptation to wheat production in a drying climate. Presentation to Regional Crop Updates, WA.