Unlocking the potential for crops in the high rainfall areas in the western region

Summary
Crop production is expanding in area, intensity and diversity in the high rainfall zone (HRZ) of the western region in response to a number of economic influences and research advances. While the potential for crop production is high, a number of physical and biological factors constrain crop production. The project had three distinct aims:

1. Define the biophysical limits to crop productivity in the HRZ areas of Western Australia (WA) in a spatial framework.
2. Assess research needs for the development of high rainfall cropping and undertake a key land use capability project.
3. Build senior research capacity in the western region.

The project achieved its aims.

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Conclusions
The project concludes that there is large unrealised potential for cropping in the HRZ. It is estimated that 1.2 million hectares in the WA HRZ are suitable for cropping in any year from a biophysical and rotation viewpoint. The yield potential is estimated to be 5-6 tonnes/ha for wheat and 3-4t/ha for canola in the HRZ of WA. Current yields are at only 50% of the potential, indicating opportunity to lift yields in the region. Moving from the present cropped area of 830,000ha to 1.2 million hectares, assuming 75% is sown to wheat and 25% to canola and moving from the present wheat yield of 2.7t/ha to 4t/ha and canola yield from 1.3t/ha to 3t/ha would more than double grain production from 1.9 million tonnes to 4.3 million tonnes. This is achievable in a 10 year time frame given the right economic settings.

The major constraints to high yields revealed by this project include subsurface waterlogging and lack of suitable crop varieties for the region.

Subsurface waterlogging during the critical tiller formation period often escapes grower notice but may be reducing yields by 30% or more - more than a 1t/ha. The project outlines the probability of that occurring and has developed some simple maps to aid grower decision making.

The project concluded that cereal ear number is the most important factor in determining grain yields and that an increase in grain number per ear and grain size are not sufficient to compensate for the loss of ears (fertile tillers). Therefore, targeting high ear number is the key to achieving high yields in the HRZ. Investigating how to achieve high ear number through agronomic management such as planting density and nitrogen (N) management requires further definition.

Water use studies identified that in most years the balance between pre and post-anthesis water use is such that delaying flowering (anthesis) by perhaps 10 days could allow more pre-anthesis biomass to be produced while still allowing sufficient water for grain fill. Further, the opportunity may exist to plant earlier; by two to four weeks depending on the break of the season. This needs to be tested with new germplasm. This may also assist in reducing frost risk around flowering, a significant constraint in the WA HRZ.

Water balance studies revealed that, in many years, more than 100mm of water may be lost from the crop viewpoint as the intense and high rainfall during winter, combined with the early stage of crop development and low temperature, mean that water escapes the crop either as runoff or deep drainage.

Modelling yield using 100 years of historical climate data allowed agronomic and breeding suggestions to be explored. Modelling also provides a means for growers to put their cropping practices into perspective regarding seasonal expectations.

The WA HRZ has great potential for more area of crop and much higher yields. This project has gone a long way towards showing the path to achievement of that possibility. Economic modelling has shown how that might sit in an economic
Recommendations

The results of this project have been widely published and extended in a variety of forms. Ongoing effort is required by the grains industry to ensure the insights of this project are carried forward.

Further research is needed into how to achieve high ear number through agronomic management. A framework of information that includes a matrix of seeding rate, N nutrition tactics, soil type and waterlogging likelihood is indicated.

Quick maturing long-season wheats may provide opportunities to utilise the complete growing season and available water in the HRZ. Searching and breeding for such genotypes is a top priority for future research.

Water will escape annual cropping systems in the WA HRZ in almost all years and often 100mm is lost. A project aimed at modelling water loss at landscape level and at determining whether this water can be caught and diverted to high value crops is recommended.

The value of surface and subsurface treatments to relieve waterlogging and harness excess water for other uses as described above is also required. The value of the land and the cropping potential may well make this profitable in the medium term.

Outcomes

The project gave a clear view of the major biophysical constraints to crop production in the HRZ. A path for development of cropping strategies and future varieties is defined. Yields of over 5t/ha for milling wheat and 3t/ha for canola were achieved. The area suitable for cropping in the WA HRZ is identified.

The project provided evidence that crop yield potential is high in the HRZ of WA and can be achieved, but with considerable variation between years, depending on waterlogging events. The importance of subsurface waterlogging was established, whereby water perched over the clay duplex B horizon, while not always visible at the surface, constrained fertile tiller production and in turn yield. The crop can otherwise look healthy, so the problem may be hidden from growers. The main impact of the waterlogging was to reduce head numbers per square metre. Experimentally and in comparison with values in the literature, it was established that there is a robust relationship between fertile tiller number (head number) and yield, whereby each 100 heads gives a tonne of wheat. It was further established that the plant was unable to fully compensate for low head numbers by setting more spikelets or grains, or larger grains. Some compensation took place, but not enough. Head number is not readily estimated by casual examination of crops and growers may not be aware that they have sub-optimal head numbers. It is recommended that as a first step to attaining high yields in the HRZ with existing milling wheat varieties, growers aim to establish 500 heads/m\(^2\). While this will not achieve 5t/ha every year, due to other constraints, it will maximise the opportunity to get high yields if the season is otherwise favourable. It was found that subsurface waterlogging may reduce fertile tiller number by half and this could happen in 50% of years, based on long term weather records. The critical time when waterlogging most affects fertile tiller number is at the tiller formation stage, around mid July with a May planting date. Seeding rate, N nutrition and control of waterlogging by drainage, beds or similar means will assist but more work is required to define the best combinations of seeding rate and N fertiliser to achieve the highest number of heads possible in any year. Farm profits are very sensitive to yield and the project showed that high yields are readily achievable in the WA HRZ.

The project uncovered some apparent weaknesses in existing varieties’ adaptation to the HRZ. Using the otherwise well adapted variety Wyalkatchem\(^0\) as a yardstick, detailed biomass and yield component analysis across seasons suggests the crop could flower up to 10 days later without suffering undue water stress in the post-anthesis period. There also appears to be a germplasm-based constraint to the number of grains that are set per ear.

Achievements/Benefits

1. The project has defined the HRZ in the south of WA. This includes 21 shires in the annual rainfall zone of 450-750mm. There are 4.8 million hectares of land in the region and about 3.7 million hectares are freehold land used for agriculture. At present, 864,000ha in the region are used for annual cropping in any year. Land capability assessment indicates that about 50% of land in the western and 70% in the eastern half of the WA HRZ is potentially suitable for annual cropping. Economic and risk analysis indicates that, for a range of grain and wool prices, profitability is maximised if 20-40% of the farm is cropped. Profit is similar over this cropping range when examined in conjunction with animal enterprises, giving individual growers...
6. The project has produced the first detailed insight of water use by annual crops in the WA HRZ, where limited research has density is reduced. This is a fertile area for further research.

mitigating against high grain numbers per ear and, as outlined above, the crop cannot compensate sufficiently when head grain yield. This is explored further below. The project also identified that current varieties may have genetic constraints sowing opportunities in the HRZ. A balance is reached between accumulation of dry matter and conversion of dry matter to grower normally ‘losing’ one month of growing season. Quick maturing long-season wheats may provide growers with early HRZ normally wait until late May to sow the current wheat varieties to reduce the risk of frost at flowering. This results in

5. The project has identified that current varieties used in the HRZ may not fully use the whole growing season. Growers in the Department of Agriculture and Food WA (DAFWA) and AWB Landmark. As an example, lucerne in rotation with annual crops options that growers can bring to bear. These are outlined in the HRZ cropping manual developed in conjunction with the extension message in the WA HRZ.

reasons behind it as to its importance, provides a valuable benchmark for growers and should be taken forward as a powerful constraint to achieving high yields in the HRZ. In 2001, at the project’s major research site at Kojonup, no perched water table was observed and wheat and canola yields reached their estimated potentials of 6t/ha and 4t/ha, respectively. In 2002 a perched water table developed at less than 30cm below the soil surface for eight days and 50cm below the soil surface for at least 40 days at the tillering stage of wheat and at the rosette stage of canola. The wheat yield in 2002 was 3.7t/ha, 37% lower than in 2001 (5.5t/ha). This was well below the potential, largely as a result of a reduced tiller number per plant and, in turn, fewer ears per unit area. It was found in experiments and in surveys of the literature that as a simple rule of thumb, 100 heads/m² produced 1t/ha of wheat. To achieve 5-6t/ha crops, growers need to aim at setting up a crop with at least 500 heads/m². While other factors may in the end mitigate against getting a 6t/ha crop, unless such head densities are achieved the potential may never be reached. In 2002, grain size in wheat was 25% larger than in 2001 but this increase was insufficient to compensate for the yield loss resulting from the fewer ears per unit area. The number of grains set/ear rose slightly but, likewise, this increase was not sufficient to bridge the gap arising from the lower ear number. This finding, with reasons behind it as to its importance, provides a valuable benchmark for growers and should be taken forward as a powerful extension message in the WA HRZ.

4. The project further developed a simple decision support tool based on long-term historical weather data, soils and the slope in the region. Probability maps of the risk of waterlogging in the HRZ were developed. In average rainfall years the risk of waterlogging is high on the western side of Albany Highway and in low flat areas on the eastern side of the highway. In wet years (one in four years) the area prone to waterlogging expands eastward and the shires of Narrogin, Woodanilling and part of the Katanning and Broomhill shires can be subjected to mild to severe waterlogging. In dry years (one in four years) the risk of waterlogging is much less for most of the HRZ and occurs only on the western edge of the HRZ. Three probability maps are produced for dry, average and wet years. While at this stage it is not possible to predict seasons and waterlogging risk in advance, the maps provide decision support for growers by outlining the probability of the occurrence of waterlogging and, in turn, allowing them to decide how to manage to cope with this. There are several agronomic and land management options that growers can bring to bear. These are outlined in the HRZ cropping manual developed in conjunction with the Department of Agriculture and Food WA (DAFWA) and AWB Landmark. As an example, lucerne in rotation with annual crops can dry the profile, which can delay the onset of waterlogging and mitigate the effect of subsurface waterlogging on wheat.

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6. The project has produced the first detailed insight of water use by annual crops in the WA HRZ, where limited research has considerable flexibility as to choice of rotations and enterprise mix. Grain yield is a main profit driver and increases in wheat yield above the HRZ average of 2.7t/ha have a marked influence on profit. This project indicates potential yields for the region and how growers might ‘climb the yield curve’. While it is unlikely that growers would wish to manage to full potential, given that the yield curve approaches a plateau around 6t/ha with present technology and marginal costs may exceed returns as yield limits are approached, it is clear that yields up to 4-5t/ha are profitable. The final decision on level of yield targeted by growers will be determined by their ability to manage high yielding crops and their attitude to risks associated with cropping in the region, such as waterlogging, disease and frost. It is considered that growers can realistically aim for 4.5t/ha. This means there is opportunity to produce much more grain in the WA HRZ. Using wheat as an example, if the area used for cropping is expanded from the present 23% up to 33% and yield is improved from the present 2.7t/ha to 4t/ha - quite achievable aims - then production could increase from 2.33 million tonnes to 4.88 million tonnes. At $200/t this would be worth $500 million. This is considered to be quite achievable in the next 10 years or sooner if conditions are very favourable for cropping.

2. The potential yield of wheat and canola for the region was unveiled using the Agricultural Production Systems Simulator (APSIM) simulation model and 100 years of historical seasonal climatic data. Yield potential was shown to be high for wheat and canola due to the high rainfall and long growing season. The field experiments carried out in this project achieved 5-6t/ha for wheat and 3-4t/ha for canola, indicating that high yield potential is achievable. Potential yield here is taken to mean the yield that is achievable with the soil type and climate limitations in the region that impose biophysical limits on crop performance using the production technologies of today. They assume no undue soil, disease, nutrition or similar constraints.

3. The project experiments revealed that subsurface waterlogging caused by perched water tables at shallow depth is a major constraint to achieving high yields in the HRZ. In 2001, at the project’s major research site at Kojonup, no perched water table was observed and wheat and canola yields reached their estimated potentials of 6t/ha and 4t/ha, respectively. In 2002 a perched water table developed at less than 30cm below the soil surface for eight days and 50cm below the soil surface for at least 40 days at the tillering stage of wheat and at the rosette stage of canola. The wheat yield in 2002 was 3.7t/ha, 37% lower than in 2001 (5.5t/ha). This was well below the potential, largely as a result of a reduced tiller number per plant and, in turn, fewer ears per unit area. It was found in experiments and in surveys of the literature that as a simple rule of thumb, 100 heads/m² produced 1t/ha of wheat. To achieve 5-6t/ha crops, growers need to aim at setting up a crop with at least 500 heads/m². While other factors may in the end mitigate against getting a 6t/ha crop, unless such head densities are achieved the potential may never be reached. In 2002, grain size in wheat was 25% larger than in 2001 but this increase was insufficient to compensate for the yield loss resulting from the fewer ears per unit area. The number of grains set/ear rose slightly but, likewise, this increase was not sufficient to bridge the gap arising from the lower ear number. This finding, with reasons behind it as to its importance, provides a valuable benchmark for growers and should be taken forward as a powerful extension message in the WA HRZ.

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6. The project has produced the first detailed insight of water use by annual crops in the WA HRZ, where limited research has
been done in the past. The field experiments from 2001 to 2003 revealed that crop water use was fully met by rainfall from sowing to anthesis. While there was significant demand for water during the post-anthesis period, it appeared that the crops did not come under severe stress and there may be opportunity to extend the pre-anthesis period without putting undue pressure on yield formation post-anthesis. The water use distribution resulted in a ratio of pre to post-anthesis water use of 1:1 to 2:1. These ratios are lower than the indicative value of 2:1 for limited water supply for grain filling. The lower ratios indicate that high dry matter at anthesis in spring wheat does not prematurely exhaust soil water for grain filling. This suggests exploration of later anthesis germplasm that could make better use of rainfall.

7. The project identified that considerable water was lost from the annual cropping systems in the HRZ, with no significant difference in water use between wheat, barley and canola. Winter rainfall in the June to August period is so high and evaporative demand and demand from the young crop so low that, in most years, there will be water well beyond crop demand. In excess of 100mm of water is lost from the system, either by deep drainage or surface or subsurface runoff. This has significant implications for offsite impacts on salinity and nutrient loss to waterways. Phase rotations with perennial crops and harvesting of excess water for later use on high value crops might provide a path forward.

8. The project has jointly published a manual called ‘Successful Cropping in the HRZ of Western Australia’, in conjunction with project DAW673. The manual sets out many of the findings of CSP302 and is a result of the strong relationship built between CSIRO and DAFWA during the concurrent GRDC projects.

9. At the start of this project it became apparent that the project and its subsequent impact on the farming community would benefit from close cooperation between CSIRO, a DAFWA/Landmark project and a grower/GRDC oversight group. A joint steering committee was put in place to guide the research priorities of the two projects. Annual meetings were held before each season to set priorities and oversee field day and symposium arrangements. The project team is indebted to the many growers who guided it.

10. This project received detailed guidance from the Kojonup Crop Research Group and is especially indebted to John and Caroline Young, who provided the experimental site and gave explicit advice along the way about many aspects of site management. John also provided the economic modelling component of the project. Gratitude is also due to Peter and Anna McLeay for giving up their home on a number of occasions for meetings of the group and for providing a constant reality check on what the project team was proposing, to Neil Young for asking lots of difficult questions and helping the project team think outside the square and, in the design phase, to Will Carrington-Jones, Bob Baker and Rob Warburton for their guidance.

11. The aim of this project was to provide information to growers, agribusiness, GRDC, fellow researchers and the wider scientific community as the project proceeded. This has been achieved. Formal publications prepared during the project now published, or in press, are:


Field days were held each year in conjunction with DAFWA and general discussions and presentation of data to the
cooperating grower groups and overview committee took place on several occasions. The project team is indebted to Narelle Hill, Ron McTaggart and Wal Anderson, of DAFWA, and to Landmark personnel for the cooperative arrangements put in place throughout the course of these events. The helpful input of many colleagues in eastern Australia, who shared results and approaches, is also acknowledged. Print and electronic media were used during the project whenever the occasion arose to publicise results.

12. GRDC personnel gave freely of their time and knowledge to help keep the project on track. Thanks go to Dale Baker and the Western Panel of GRDC, Bob Belford for valuable advice on scientific aspects and general approach, Phil Price for his wise counsel and Martin Blumenthal and John Harvey for project management advice.

13. An aim of this project was to build capacity in the western region from two points of view. The first aim was to build a strategic view of the cropping capacity of the region. This has been achieved and the industry is now in a position to appreciate present production and future opportunities based on an analysis of soil types, climate, potential yields and constraints. Paths to the future have been described. The other capacity building aspect was human capital. Dr Heping Zhang, the research scientist attached to this project, has built a deep understanding of the region and its special characteristics. He is now well informed to manage the new CRDC project and is seen as an expert on the Australian HRZ.

Other research

The research undertaken in this project has shown the way towards new areas for research. These are being taken up in the new GRDC Project CSP00065 ‘Delivering high yields of milling wheats in the HRZ of WA’, being carried out by the team involved in the project reported here. The new project shifts emphasis to several new areas. The first is exploration of germplasm that is better adapted to the region with three aims in mind:

1. Varieties better able to set fertile tillers under waterlogging conditions during tiller formation
2. Varieties with later maturity - by about 10 days - to test the hypothesis that there is sufficient water available post-anthesis to fill grain
3. Varieties that can be planted up to one month earlier than present practice combined with the present flowering time, or 10 days later as outlined in (2).

Germplasm has been gathered from several breeding sources, with emphasis on new material emanating from the CSIRO/AUSGRAINZ alliance that gives access to material from New Zealand and other high rainfall regions in the world.

The other aspect to be further explored is the three-way interaction between seeding rate, N nutrition and waterlogging versus non waterlogging to reliably, or predictably, achieve consistent tiller numbers in the 500-600/m² range.

The aims of the new project are summarised as:

1. Evaluate new genotypes of milling wheats for the WA HRZ define the crop characteristics and physiological traits for high harvest index and yield and work in conjunction with breeders to assist the development and evaluation of new cultivars to meet these requirements.
2. Assess how current and new wheat genotypes use resources (light, water and nutrients) to achieve high production and define, test and demonstrate the management practices needed in the WA HRZ to translate these resources into high and profitable grain yield.
3. Develop, in collaboration with WA grain growers and the Riffkin/Hill project, a decision support tool to achieve high yields and engage growers in testing and refining this tool to a stage where it can be easily and rapidly taken up across the WA HRZ and delivered to the industry.
4. Build the capacity of growers to best utilise the resources of the HRZ for crop production and build scientific capacity to address issues for the HRZ

Intellectual property summary

The information generated from the project is in the public domain and freely available to Australian high rainfall growers and their advisers.

Additional information
Poole ML, Turner NC, Young J (2002). Sustainable cropping systems for high rainfall areas of south western Australia. Agricultural Water Management 53, 201-211.


Manual, three articles in Farming Ahead and High Grains.