Innovative ways of improving crop germination and yield in a drying climate

An assortment of ideas that could be incorporated into dryland farming systems

A report for:

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2014 Nuffield Scholar

March 2018

Nuffield Australia Project No 1402

Supported by:

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Executive Summary

This report aims to discover ways grain growers in the Eastern Wheatbelt of WA can improve financial resilience by improving cropping knowledge and implement innovations based around improving crop establishment. It contains an assortment of ideas for farmers as to how they can make the most of a water limited environment.

The last 10-15 years of cropping has been a challenge in the Eastern Wheatbelt. Long-term average yields are similar but the autumn rains critical for crop establishment have been declining. Timing is everything, and although these rains can still occur, accumulated rainfall for the months of April, May and June is currently below average. This creates periods of sub-optimal soil moisture for crop establishment. Timely emergence is critical for crop yield potential. Given a favourable season and adequate soil moisture early sown crops have greater yield potential. Yield is the primary driver for financial performance providing expenditure is balanced.

Financial equity in the eastern Wheatbelt of Western Australia can change by up to (+/-) 25% annually in a cropping dependant business clearly displaying the investment risk. Continued poor results can take their toll on farmers, local communities and confidence of the financial institutions backing them; resonating far beyond the farm gate.

There can be large spatial variation of crop emergence and performance across paddocks and similar soil types. Some variation will be seasonally dependant. However, a lot of variation can be attributed to management historically and during the current season. This indicates that growers could study and measure soil moisture as part of their system to further understand the germination and establishment process. Soil moisture probes are a powerful tool for decision making based on real-time soil moisture measurement. Constant evolution of no-till seeding techniques and residue retention will further improve the soil water holding capacity, infiltration and reduce evaporation which will all ultimately improve crop yield. In addition, the merits of livestock in the cropping system need to be fully assessed to understand if they are a truly synergistic fit. Livestock grazing results in a loss of stubble cover, soil compaction and poor weed control in the pasture phase which can all impact future crop potential.

Having seeding machinery with the ability to place seed into moisture will significantly improve germination. This may be currently available machinery or modified to suit particular requirements. In the Pacific North West of USA - Washington State, seed placement deep into the soil profile known as ‘moisture seeking’ has been common place since the 1960`s.

Ongoing breeding for long coleoptile length crops would benefit cropping enterprises in the low rainfall areas in Australia. The ability to chase stored moisture at depth in the soil profile would significantly improve germination. Maximising crop establishment is critical to optimise yield potential.

In Australia, farmers have some of the most challenging conditions for crop establishment and yield in the world. To improve cropping system reliability, growers need to add incremental improvements. This report details a combination of ideas and further refinement from Australia and overseas. One simple solution is not available.

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Foreword

My wife Tryphena and I own and operate a 10,000ha dryland farm at Bencubbin in the eastern central Wheatbelt of Western Australia. Approximately 270kms north-east of Perth in a region with 300mm of annual precipitation with winter dominance. We are a cropping-focussed operation with 6,000ha wheat, 2,000ha barley grown annually with the remaining 2,000ha arable for fallow and opportunistic pulse cropping.

I am a third-generation farmer with full control of the business since 2003, aged 29, after taking over from my parents David and Annette. I have accumulated 25 years of experience on our farm which has allowed me to appreciate the complexities and risk in our environment. The stakes are high, with management and attention to detail paramount, but we are still at the mercy of the weather. The seasons have changed to become drier. This may not be a serious long-term anomaly, but we need to adapt to current conditions.

It has been a long time since we got machinery bogged at seeding, and this is a great indicator of the current autumn and early winter rainfall deficit. Drier autumn conditions and lack of seedbed moisture have created extra challenges to our operation; the pressure to maintain yields and profits with an ever-increasing cost base is constant.

The foundation of our cropping season is timely and needs uniform crop emergence. This is obviously impossible with zero moisture but there are still opportunities presented in most years for germination. This can be sub-optimal and short-lived but still an opportunity.

My Nuffield Scholarship topic “Innovative ways of improving crop germination and yield in a drying climate” was born through necessity to answer the question, ‘How can we improve our management and techniques for better crop establishment and in turn a better stronger business?’

The Eastern Wheatbelt region is home to thousands of hectares of naturally fertile prime land for cropping. Sadly, the recent seasons have taken their toll with numerous farms for sale. The price of risk is reflected, and sadly consecutive failures for some have meant it’s time to abandon their family legacy. Behind the intimate farmer’s attachment and passion that runs deep in their veins is a business that simply cannot sustain a run of crop failures.

My scholarship travel included Australia, Canada, USA and the UK. It was a challenge determining the countries to visit as drier environments like Northern Africa were based around subsistence farming, Iraq and Syria had a wealth of research into germination and dryland cropping systems, but the travel risk too high.

Research included three weeks in eastern Australia, necessary to see local innovation in practice. I visited machinery manufacturers, CSIRO, no-till organisations and many farmers.

Four weeks in Canada focused on a specifically dry marginal area known as Swift Current. They had just experienced five wet years, confidence and land prices booming and there were no issues with crop establishment!

In the USA, cropping areas in Washington State vary from 750mm annual precipitation at Pullman in the Palouse to 150mm at the Horse Heaven Hills near Oregon. With pressure to get dominant winter crop established before snowfall on marginal conditions, the challenges were similar and a highlight of the tour. A well-organised tour around Washington State University at Pullman and living on farm in Ritzville to discover their techniques was excellent. A visit to South Dakota and Texas was also worthwhile.

The final leg of the trip was the United Kingdom (UK) to visit the Shelbourne stripper header factory, corporate farming investors and other Nuffield Scholars.

Acknowledgments

I would sincerely like to thank my investor the Grains Research and Development Corporation (GRDC) for this remarkable opportunity to travel, learn and share, as well as the prestige of being part of the Nuffield family. I am very grateful.

To my wife Tryphena for keeping the office going, her support of my scholarship and strength looking after the family. To Tahlia, Savannah, Kaden and Makenzie for their continual contact and help at home.

On the farm I thank my staff Troy Beard and Brendan Davis, consultant Shane Sander and agronomist Darren Marquis who allowed me to remove myself from the farm business for the first time.

To Clint Munro for his assistance and knowledge in Canada.

John Kirkegaard, Karen Sowers and Curtis Hennings for organising the most memorable and productive parts of my travel in the USA.

To all the diverse businesses, research institutions and Nuffield contacts who kindly welcomed and shared their valuable time.

My travelling partners on the Global Focus Program for creating such a unique experience and lifelong friendships.

Thank you to Kelly Manton-Pierce and Nicola Raymond for their editorial assistance.

My 2014 Nuffield Scholarship is just the start of a unique and privileged journey.

Abbreviations

CSIRO	Commonwealth Scientific and Industrial Research Organisation
EWB	Eastern Wheatbelt (of Western Australia)
GPS	Global Positioning System
GRDC	Grains Research and Development Corporation
Ha	Hectare
MPCI	Multi-Peril Crop Insurance
PAW	Plant Available Water
PNW	Pacific North West (region in western USA)
USA	United States of America
UK	United Kingdom
VRT	Variable Rate Technology
WA	Western Australia
WA	Washington State
WSU	Washington State University

Objectives

- To improve financial resilience by improving cropping knowledge and systems, based around crop establishment.
- To investigate moisture requirements for crop germination and spatial variance.
- To present a collection of ideas, techniques and innovation for adaption now and into the future for implementation into dryland cropping systems.

Chapter 1: Introduction

1.1 Productive value of the Australian grains sector

Australia has a rich history of agricultural production. The forecast total production for all grains and oilseeds in Australia in 2016/17 was 58,058,000 tonnes from 20,796,000ha of land (ABARES, 2017). In terms of export earnings, this is forecast at $10.6 billion equating to 20% of the total $47.734 billion value of agricultural exports. With a growing world population and as an export-based nation, it is critical to maintain production of grain and preserve the productive output of farmland.

The dryland cropping region of Western Australia (WA) is a significant contributor to Australian grains production. WA produces about 14 million tonnes of grain each year from around 4,000 rain-fed farms ranging in size from 1000 to 15 000 hectares (ha) (Dept. Primary Industries, WA. 2017).

1.2 Rainfall decline

The reliance on rainfall to produce a crop can expose areas like the Eastern Wheatbelt (EWB) that lie at the extremities of the WA cropping region to significant financial risks. Rainfall in the south-west of WA has declined rapidly since the mid-1970s (IOCI, 2005). The rainfall isohyets have moved westward when annual rainfall from 1910 to 1999 was compared to annual rainfall that fell from 2000 to 2011 (See Figure 1).

For example, in Dalwallinu (a town in the Wheatbelt region of Western Australia, located 248km from Perth), the average annual rainfall of 325mm in 1910 to 1999 dropped by 50mm to 275mm by the period 2000 to 2011 (Guthrie et al, 2015).

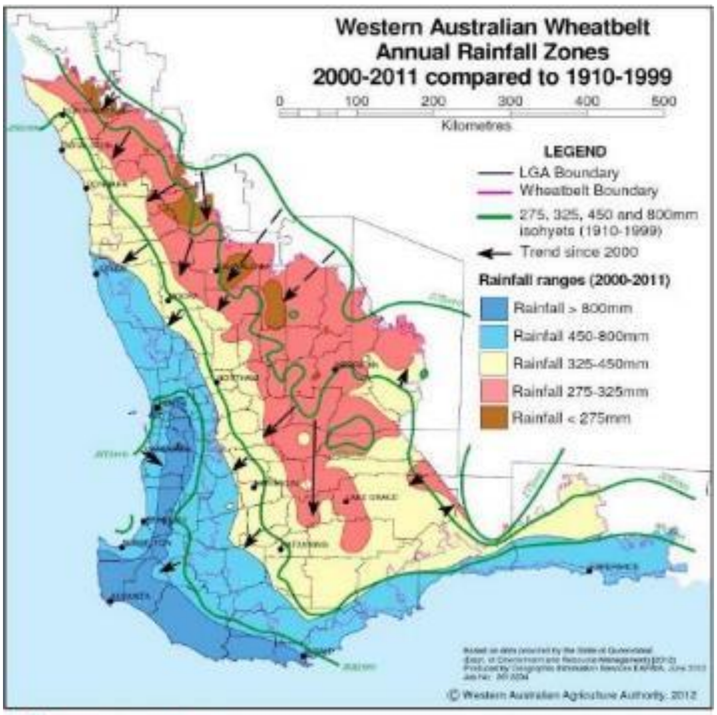

Figure 1: Drying patterns of south-west, Western Australia (Source: Evans, F. Dept. of Agriculture WA. (2015)

Seasons are changing, and the prospect of climate change are constantly debated. However, the data to support the decline in rainfall in WA is very robust. Rainfall is everything to a cropping business in a rain-fed system. Compounding the effect of total annual rainfall decline in WA is the large reduction of rainfall in the months for crop establishment, which in the Eastern Wheatbelt is April, May and early June. This is critical for timely emergence and early growth to provide potential for the season.

In the period 1949-2014, in 56% of those years 70mm of rain fell in 70 days at Bencubbin in the period 10 April-18 June (See Figure 2). In the 29 years of less than 70mm rainfall in 65 years of data, 12 years of deficiency has occurred in the last 15 years 2000-2014 (Australian CliMate, 2015).

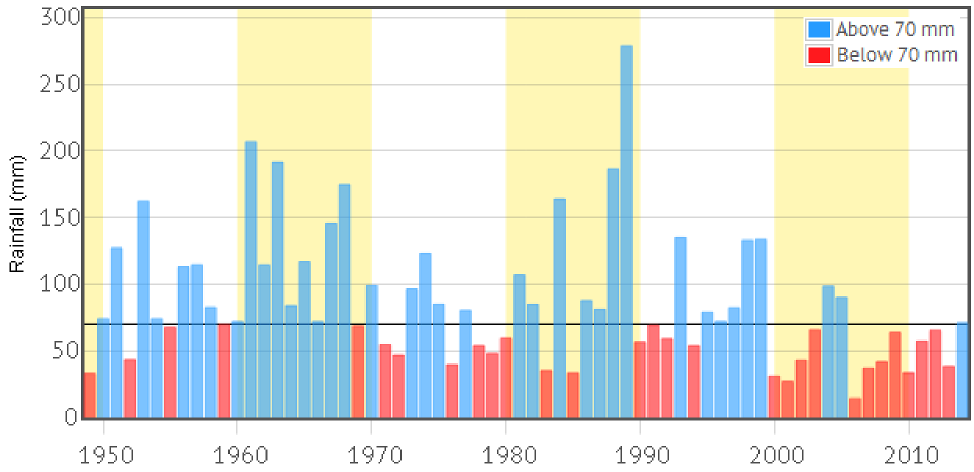

Figure 2: Consecutive 70-day rainfall totals from 10 April-18 June from 1950 to 2010. Source: www.australianclimate.net.au, 2015.

1.3 Climatic impact on grains production

Annual rainfall decline has significant implications for crop growth. The "French and Schultz" equation for yield potential in wheat, focusing on the relationship between yield, water use and climate (French and Schultz, 1984) is:

Yield potential (Kg) = growing season (Apr-Oct) rainfall (mm) - 110mm for evaporation x 20kg/ha/mm.

For example, using this equation demonstrates in the case of a loss of 50mm of annual rainfall in Dalwallinu during the growing season, would equate to a potential loss of 1tonne/ha of wheat yield or $200/ha loss farmgate value if wheat is valued at $200/tonne.

Not only is the lack of winter rainfall affecting yield potential, the lack of seedbed moisture at seeding further exacerbates the problem, potentially shortening the growing season. Timely emergence is critical for crop yield potential with early sown crops having a greater yield potential with the availability of adequate soil moisture. WA-based trials have shown a yield penalty of 35kg/ha/day ($8.75ha/day) for late sowing at Mullewa-Merredin, north-east WA (The Wheat Book Principles and Practice, 2000). The optimal time for flowering is a balance between frost risk and drought stress, both of which occur during the growing season in EWB. Under the observed current weather patterns, farmers are forced to push the boundaries for optimal seeding and utilise moisture when it's available.

1.4 Constant agronomic improvements

"Australian farmers are world leaders in dryland farming, natural resource management and sustainable agriculture, but it's hard to be green when you're in the red" (Batt, Peter J. 2015).

In WA, over 88% of respondents surveyed in 2008 had adopted no-till conservation farming (D'Emden et al, 2008). No-tillage or zero tillage is a farming system in which seeds are directly placed into untilled soil which has retained the previous crop residues (Victorian No-Till Farmers Association website, 2017). This practice results in less disturbance to the soil allowing for significant improvements in soil structure and reduced moisture loss from the seedbed at seeding. Despite these improvements, no-till has significantly buffered farmers against poor seasons but there is always a breakeven point where cropping becomes unviable.

Cropping systems in the EWB need further refinements to maintain viability in the drier years. A positive, financially sustainable future will require a combination of technologies and management to help adapt to the decline in rainfall. The soil, a farmer's greatest asset, must be improved structurally and nutritionally to be more conducive to the drier seasons. Improving water storage and rooting depth for moisture exploration (known as plant available water (PAW)) is necessary to store moisture deeper away from the demand of evaporation.

1.5 The impact of moisture on the bottom line

The eight years 2006-2013 (Including 2006 and 2013) have seen a marked variation in seasons in the region on the basis of effective crop rainfall. (Refer to Table 1). Effective rainfall being growing season rainfall (April-October) plus 30% of summer rainfall. Summer rainfall can be very patchy, however if moisture is conserved by chemical weed control it can have a significantly positive effect on crop yield. Specifically:

- An extra 86 millimetres of rainfall (in 2011) and 50mm (in 2012) was stored in the profile where summer weeds were controlled, compared to sites where weeds were not controlled.
- An extra 69 kilograms of N/hectare (in 2011) and 45kgN/ha (2012) was also available for the following crop.

- The economic benefit of every $1/ha spent on herbicides to control summer weeds was $8/ha (Summer weed control, GRDC, M. Williams, 8/1/2016).

Prospective EWB seasons as detailed in Table 1 highlight the seasonal variability and its effect on crop yield. Approximately 40% of the seasons have been poor, 30% average and 30% good. (See Table 1). Profitability from the variable seasons will further be determined by grain prices however yield is the major driver with all else being equal. This creates financial variability from -$118.40/ha loss in a poor season to $214.80/ha profit in a good one. (Table 2)

	Poor season	**Average season**	**Good season**
Effective rain (mm)	<150mm	150-200mm	>200mm
Years	2007, 2010, 2012, 2013	2006, 2009, 2013	2008, 2011, 2013
Wheat yield	0.3-1.0t/ha (say 0.8 t/ha)	1-1.8t/ha (say 1.5 t/ha)	1.8-3.0t/ha (say 2.4 t/ha)

Table 1: Categorising 2006-2013 seasons in the EWB according to effective rainfall Source: Kirk, G. How to Farm Profitably in the Eastern Wheatbelt of WA

Returns from good seasons must be appropriated to improve business strength and allow survival through the poor ones. A poor season of 0.4t/ha is possible every ten years, and this will have a significant effect on business health with a likely 20% - or more – reduction in equity (Table 2). According to the Planfarm Bankwest Benchmarks, which is a WA farm consultancy report into the financial and production performance of broadacre farm businesses, there are still farmers prospering in this environment with the top 25% of farm businesses in the EWB region generating on average $42.56/ha more than the Planfarm Bankwest benchmarks (Greg Kirk, Planfarm, 2014).

Wheat Cropping costs

Yield T/ha	0.8	1.5	2.4
Crop Income/ha	**$216.00**	**$405.00**	**$648.00**
Wheat price ($/T FIS)	$270.00	$270.00	$270.00
Crop Costs/cropped ha			
Seed	$20.00	$20.00	$20.00
Fertiliser	$45.00	$50.00	$60.00
Lime & Gypsum	$10.00	$10.00	$10.00
Chemical	$45.00	$47.50	$50.00
Crop Insurance, contract etc	$15.00	$20.00	$25.00
Grain freight & selling costs @ $43/t	$34.40	$64.50	$103.20
Fuel & Oil	$24.00	$24.00	$24.00
Repairs	$23.00	$23.00	$23.00
Labour	$18.00	$18.00	$18.00
Total crop costs	**$234.40**	**$277.00**	**$333.20**
Fixed costs/cropped ha			
Admin, rates, phone	$21.00	$21.00	$21.00
Operating expenses/ha	**$255.40**	**$298.00**	**$354.20**
Operating surplus/ha	**-$39.40**	**$107.00**	**$293.80**
Personal costs/cropped ha	25	25	25
EBIT/ha	-$64.40	$82.00	$268.80
Ave asset/ha	$1,200.00	$1,200.00	$1,200.00
ROA	-5.37%	6.83%	22.40%
Finance costs and lease/cropped ha	30	30	30
Plant & machinery depreciation/cropped ha	24	24	24
Net Profit/ha	-$118.40	$28.00	$214.80
Equity	$1,000.00	$1,000.00	$1,000.00
ROE	-11.84%	2.80%	21.48%

Table 2: Eastern wheatbelt cropping economics based on different yield potential. Source: Gillett, N.

When reviewing the financial model of an EWB cropping farm we can appreciate the seasonal variability experienced, (Refer to Table 2). It must be understood that not all farm operators are equal and the analysis utilises average benchmarking figures from the industry, consultants along with actual author data. The table is based on only wheat grown for 100% of arable land. Input will vary enormously from farm-to-farm; however the data paints a picture of potential investment at risk especially coupled to scale and seasonal variation. The average cropping area in the EWB is 4,521ha (Agvise 2015 Client Benchmarking Survey).

According to Greg Kirk, Planfarm, in 2014, the key messages from the most profitable operators in WA are:

- Adopt a conservative approach to debt
- Efficiency of labour & machinery is important
- Sheep if you and they are compatible
- Pay attention to your costs every year.
- Attention to detail – develop a culture of doing things well.
- Hard work
- Take the opportunities when they come along.

These points reinforce that strong management skills are critical to ensure the financial viability of any farming business where there is seasonal variability. Applying knowledge, technologies and management practices to maximise crop germination and therefore yield in marginal seasons in combination with strong management skills is vital to underpin the overall financial performance of EWB farmers.

Chapter 2: Strategies for making the most of water

2.1 Moisture requirements for germination

The complex process of crop germination requires one major ingredient – soil moisture. The seed absorbs soil moisture and seed germination will commence once the water content of the seed reaches 35-40% (Setter et al, 2000). The challenge is to maintain soil moisture in a rapidly drying phase or in variable soil conditions.

Seasonal moisture and soil type combine to form sowing opportunities in the EWB. Between 25 April – 25 May is generally acknowledged as best timing for crop germination and emergence, although the years since 2000 have been drier during this period. Germination opportunities have still existed, due mainly to stored moisture accumulation from out of cropping season summer rainfall.

Figure 3 shows sowing opportunities on loamy duplex soil at Merredin, WA. The moist seedbed refers to 0-100mm depth and topsoil 0-200mm. The blue colour represents reliable soil moisture conditions for crop germination and the red colour represents dry top soil with no chance of germination. Having said this, there is still a chance of moisture deficit and seedling stress post sowing.

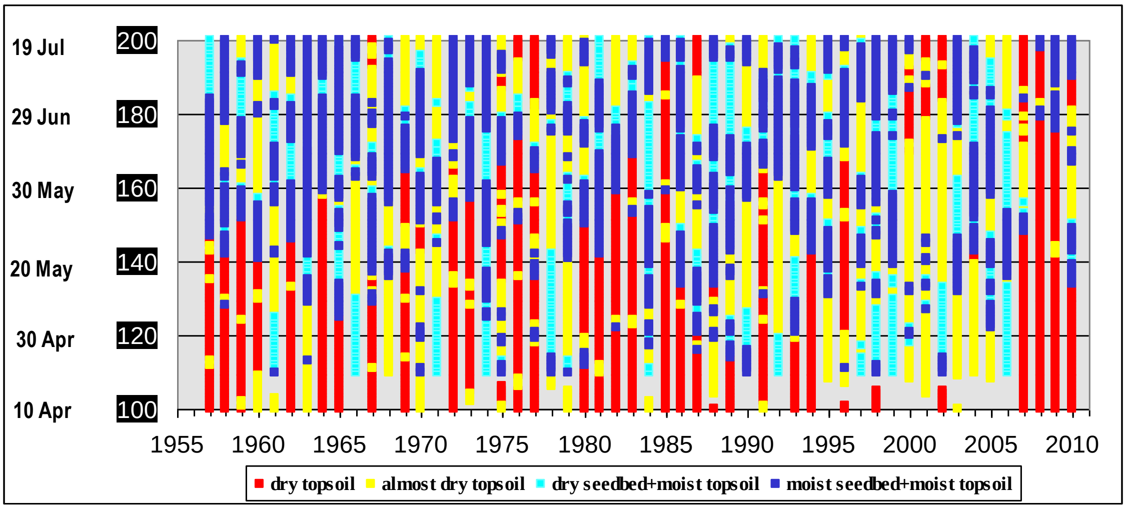

Figure 3: Sowing opportunities on loamy duplex soil at Merredin, WA (1957-2010). Source: Abrecht, DR D., Department of Agriculture and Food, 2011)

A scientific measure for soil moisture is 'water potential' (WP) which is the potential energy of water per unit volume relative to pure water in reference conditions. Water potential quantifies the tendency of water to move from one area to another due to osmosis, gravity, mechanical pressure, or matrix effects such as capillary action ref. Water potential is typically expressed in potential energy per unit volume (Ψ or MPa) (University of California, Davis, 2000).

Research shows that many cereal species can germinate at soil water potential well below those that maximise plant growth. For example, at water potentials from zero to -1.0 MPa, and where the soil atmosphere begins to drop below 99% relative humidity (Papendick and Campbell, 1981), the germination rate is near maximum (Rogers and Dubetz, 1980; Blackshaw, 1991).

A study by Wuest et al (2012) from the US Department of Agriculture, measured the soil WP for germination of winter wheat (Triticum aestivum L.) with data showing that germination was rapid (3 to 4 d) in soil at water potentials above -1.1 MPa and slower (4 to 5 d) at water potentials that ranged from -1.1 to -1.6 MPa. Below -1.6 MPa, less than half of the experimental units achieved the cut off criteria of 75% germination with 5mm radical (embryonic root) length within 25 days.

In semi-arid climates, and especially the EWB, seed is often sown into soil with inadequate water for rapid germination. Distinguishing between adequate and marginal water can be difficult without scientific equipment to determine water potential. The practical method is to dig around and go by feel; a somewhat inaccurate and immeasurable approach.

2.2 Stored soil moisture measurement using probes

Soil moisture levels will vary with planting depth, machinery used, rotations and residue management but soil moisture probes can be used in both irrigated or rainfed systems to determine the depth of wet soil by measuring volumetric water content. To build knowledge of soil moisture and germination interaction, accurate measurements can be collected for different soil types and positions in the soil profile. Decagon Devices inc. at Pullman, in

Washington State, USA, supply a range of innovative soil moisture devices, which are accurate instruments with data readings available via telemetry or manual data capture. A basic set-up single sensor investment is approximately AUD $1,400 (ICT International. NSW, Australia).

The sensor in Figure 4 is quite large, measuring 9.6 cm (l) x 3.5 cm (w) x 1.5 cm (d). These also have a temperature sensor included which allows the relationship between soil moisture and temperature to be analysed.

Figure 4: MPS-6 Calibrated Ceramic Water Potential Sensor. Source: Decagon Devices. (April 2015)

Localised soil moisture measurement using water potential sensors by farmers in the EWB will enhance knowledge of available soil moisture and germination potential. Valuable data will allow better decision making and methodology for germination success by:

- Understanding the moisture requirements for germination according to different soil types.
- Understanding the relationship between seed depth and soil moisture.
- Understanding the temperature and moisture interaction required for successful germination.
- Understanding the drying phase of soil based on different soil types, seed depth and stubble cover.

These products are not currently widely used in Australian broadacre agriculture. The author believes more research needs to be done on a micro level of measuring localised moisture for germination around the seed.

There is significant knowledge on PAW from deep soil moisture probes installed widely throughout Australia to provide real time data throughout the season. There are 22 public access sites in WA using GRDC funds and 60 private installations (Precision Agronomics Australia, 2017). As shown in Figure 5, these probes provide valuable information for cropping yield potential and input usage. Greater utilisation of soil moisture probes on farm would allow greater knowledge on PAW and water usage throughout the season if installed in the crop zone.

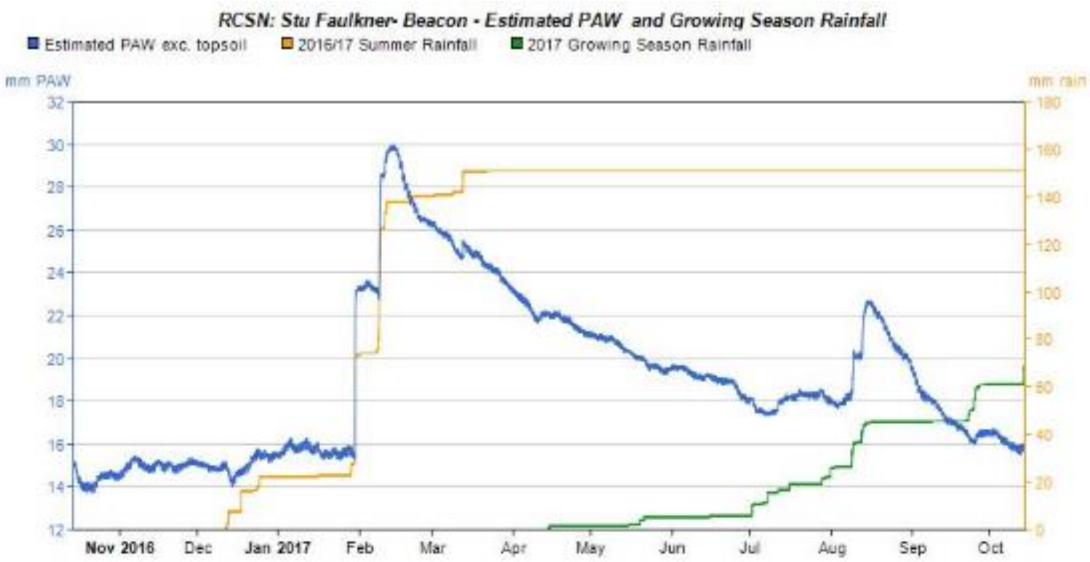

Figure 4: Local data captured from soil moisture probe. Source: Precision Agronomics Australia, 2017

With current access to real-time soil moisture probes EWB farmers can accurately assess stored soil moisture available to their crop and moisture usage. As previously stated yield is determined by moisture available.

Soil moisture probes will assist EWB farmers to make better management decisions by:

- Knowing moisture levels in autumn (pre-seeding) to help make decisions regarding optimised crop type, planting date and fertiliser inputs for individual paddocks.
- Tracking the data during the growing season to observe how deep rainfall events are soaking to fill the sub soil.
- Observing where roots are active and using this information to assist in making nitrogen application decisions.
- Observing daily crop water use and as season progresses into spring and calculating how much moisture is left in the 'bucket' for grain fill.
- Predicting yield potential with soil moisture profile in Spring to determine if extra nutrition or fungicide applications are worthwhile to meet expected returns. This reduces risk and unnecessary financial exposure.
- Predicting yield based on historic trends in crop water use in spring (3 or more years moisture probe data is usually required for this).
- Understanding the interaction between moisture, temperature and nitrogen mineralisation (agbyte.com.au)

On a macro level - large in scale or scope – soil probes provide significantly useful information for management of moisture.

2.3 Soil type impacts moisture at seeding

Soils in the EWB vary from heavy clay loams to course gritty sands and gravel. Ironically, early farm selection and cropping was based around strong heavy clay loam soil types with Salmon Gums (Eucalyptus salmonophloia) being the dominant vegetation. This was primarily due to this soil type having naturally high levels of nutrition prior to the widespread adoption of synthetic fertiliser. Heavy clay soils have the ability to yield well in higher rainfall years but struggle in the dry years.

Typically, an air dry, heavy clay loam soil will require ~10mm more rain than a sand to bring the soil to a state where water is available for plant growth (soilquality.org.au, 2017). Heavy, clay loam soils are also fine textured and have a large water storage capacity useful in better seasons and for storing summer rainfall. However, they take longer to wet to depth and generally store moisture closer to the soil surface. The consequence is water loss happens more rapidly in clay compared to sandier soils especially at the beginning of the cropping season when soil evaporation is high and rainfall events are small (Abrecht, 2015). Lighter sandier soils are now favoured by the author as being more forgiving in poorer years. See Figure 6 and 7.

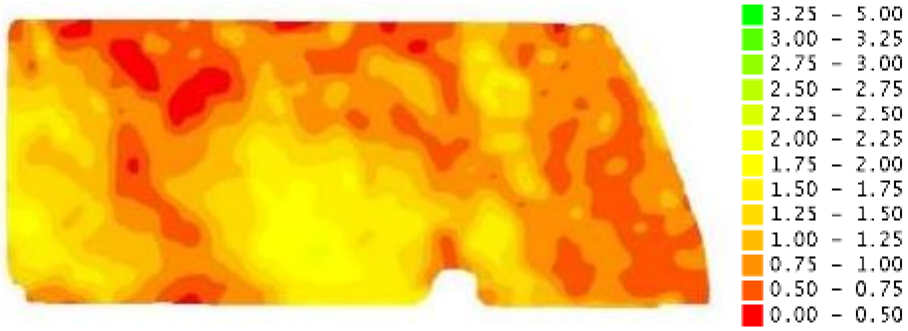

Figure 65: 2007 Yield map, Heavy clay-based soil types yield poorly in dry years. Source: Gillett, N. (December 2016)

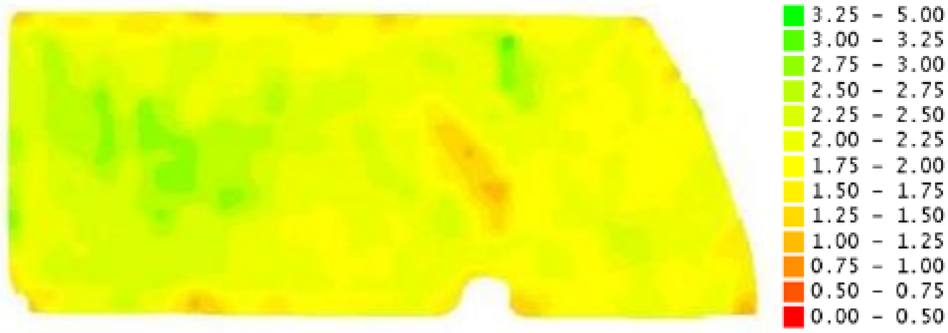

Figure 7: 2008 Yield map, same paddock in a wet year. Source: Gillett, N. (December 2016)

2.4 Soil cover essential to preserve soil moisture

Retention of crop stubble residue on the soil is vital for moisture infiltration, retention and to enhance microbial activity and soil life. “It’s like chocolate for the soil!” (Smith, 2003). The widely accepted no-tillage method of crop establishment has allowed many growers to start this process. Building the soil up to worthwhile levels can take years in areas with variable cropping yields and biomass growth.

Figure 8 shows a heavy clay-based soil type in the author’s paddock called Malkana No 4. Wheat was sown 75mm deep into moisture in warm, drying conditions. The value of crop residue leftover from the harvest for moisture retention, along with subsequent improved germination, is noticeable due to poor distribution. Header residue concentration leftover from previous seasons has helped maintain soil moisture for longer, resulting in a better germination. The zones of concentrated residue in the soil are where the green wheat crop is noticeable. This shows the benefit of residue for moisture retention, although the results observed cannot be replicated across the paddock if low EWB residue levels are evenly distributed. As shown in Figure 9, the author concluded that poor crop germination is not confined to Australia, it is an issue in all regions such as Throckmorton in Texas.

Figure 6: Uneven distribution of harvest residue affecting germination. Source: Gillett, N. (July 2013).

Figure 7: Poor crop establishment at Throckmorton, Texas, USA. Source: Gillett, N. (September 2014)

2.5 Livestock – the conflict for cover

Running sheep and lambs is a synergistic enterprise for farm businesses in the EWB. This system is very complimentary to the cropping phase as sheep and lambs graze post-harvest stubbles and are run through winter on paddocks rested from cropping, eating self-sown crops and weeds. Leaving a paddock rest as a pasture can provide a disease break, allow nitrogen to mineralise and provide an opportunity to control weeds. Benchmarking figures show an average return for sheep of $64 per winter grazed ha in the EWB (Agvise Management Consultants, 2010-2016). However, this figure of return is highly variable from $19-$108/winter grazed ha) and difficult to measure due to seasonal conditions affecting stocking rate and with machinery costs and labour not always correctly allocated to the sheep and lamb enterprise.

With the current moisture deficiencies at planting, livestock do however compromise the cropping system with regard to germination in marginal conditions. Sheep eat large amounts of stubble materials, especially when little seed is left with harvest residue on the soil surface. Many of the smaller fragments, such as shattered leaves, are trodden into the soil minimising particle size and the mulching effect on the soil. Roughly 3-5 tonnes per hectare (t/ha) of stubble is present at the start of grazing and typically reduced to 1-2t/ha when sheep by the end of the grazing period. According to soil experts, about 1.5 tonnes of material per hectare (150 grams per square metre) is needed to protect soils and minimise the risk of soil erosion (Sheep: The Simple Guide, 2012).

Figure 8: Soil cover loss from grazing Source: Gillett, N. (September 2015)

With maintaining friable soil structure paramount, the loss of stubble cover from grazing can reduce moisture retention and have a negative effect on germination. Figure 10 from the author's paddock 'Yammaling No 4', shows significant soil cover loss from grazing. The over grazed clay soil pictured was previously the lowest yielding crop area with most nutritious straw further exacerbating uniform residue retention. When the soil is moist, livestock significantly compact the soil surface layer whilst grazing and camping, further affecting soil friability required for germination.

Figure 9: Soil structure degradation from grazing moist soils creating a poor seedbed Source: Gillett, N. (September 2015)

As shown in Figure 11, in marginal seeding conditions this compacted surface layer breaks up into clods creating large air pockets that rapidly dry the soil out and reduce the imbibition of moisture to the seed due to critical seed-soil contact.

Soil structure damage (Figure 11 & 12) from livestock has a negative interaction with soil moisture as seen in figure 12. This shows the stubble effect on fallow efficiency, with stored soil moisture with/without grazing at Temora, NSW on 16 March 2010. It shows the 'no graze' (black solid line) and combined grazed treatments (grey solid line) relative to drained upper limit (grey dashed line) and crop lower limit for wheat (black dashed line). The outcome is that the additional ~50 mm of water stored in the no-graze treatment is present at depth, implying the difference is due to improved infiltration rather than reduced evaporation (Hunt, et al, 2011).

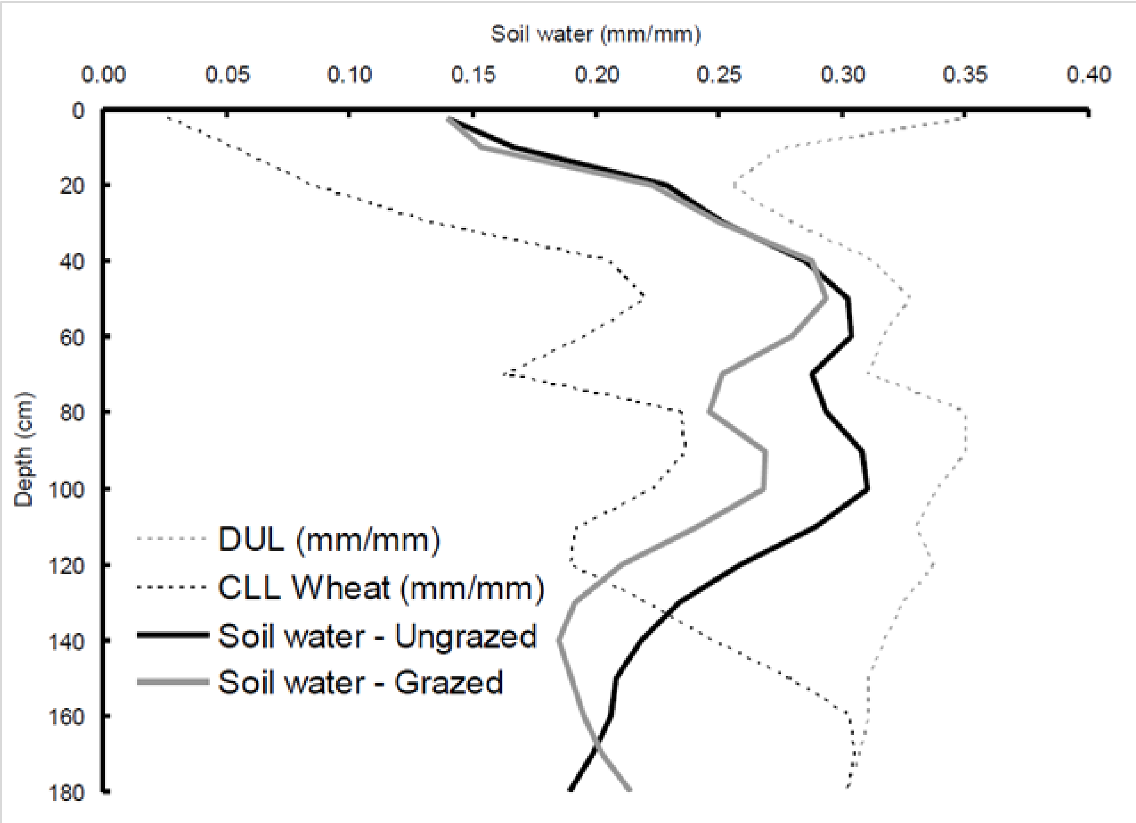

Figure 10: Stubble effect on fallow efficiency. Stored soil moisture with/without grazing Temora etc Source: Hunt, J. (February 2011).

When revisiting the "French and Schultz" equation for potential grain yield, just 25mm of stored moisture will produce 500kg/ha wheat or $100/ha on-farm at $200/t farm gate price. If the loss of yield from delayed germination due to residue loss and soil structure decline is added, it can easily negate the advantage of livestock in the system. WA-based trials have shown a yield penalty of 35kg/ha/day ($8.75ha/day) for late germination due to decreased soil moisture in the north-east zone of WA (The Wheat Book, 2000).

Negatives of running sheep in the EWB:

- Loss of soil cover, compromised stored moisture potential and soil structure and effect on crop germination.
- Consumption of essential crop stubble required to maintain soil moisture
- Soil compaction from winter grazing or after summer rainfall leading to poor seed bed for germination and higher seeding fuel costs.

- Compromised weed seed set control in pasture/fallow phase due to the trade-off between maximising winter grazing weed growth and spraying early to stop seed set control for the following crop.
- Time associated with livestock management compromising cropping decision making and operation timeliness.

Positives of running sheep in the EWB:

- Sheep can provide regular cashflow and an alternative income stream during years when crop yield and income in low.
- Sheep need to occupy more grazing area in poor seasons and this can reduce land available for cropping reducing potential losses from cropping exposure.

2.6 No-till in practice. The art of stubble retention

Dwayne Beck, from Dakota Lakes Research Farm in South Dakota, USA, is a world-renowned passionate no-till advocate for practices that improve soil structure. Figure 13 shows Mr Beck demonstrating perfectly structured no-till soil after significant precipitation. According to Mr Beck, no-till enables macro pores to form in the soil which allow superior movement of water into the profile and promote earthworms and soil biota. He also stated that no-tillage systems are more than reducing tillage; they are systems that incorporate diverse crop rotations for holistic land management.

Figure 11: Building perfect soil structure after significant precipitation in South Dakota. Source: Gillett, N. (September 2014)

Conserving precious moisture

The author visited Swift Current, a small city in southwest Saskatchewan in Canada. With an annual rainfall of 377mm (265mm rainfall and 119cm snow melt) (Govt. of Canada, 2017), it is generally regarded as a marginal cropping area. For farmers in the region, water is the most limiting factor for crop yield. To manage this, they manage water efficiently, increase water supply by water conservation and standing stubble – preserving the previous season's stubble. Research by Swift Current Research and Development Centre was targeted on a systems approach to maximise moisture. The centre outlined the benefits of standing stubble in their region, which acts as a snow trap and maximises moisture retention. It also shields spring wind and heat. Researchers at the Swift centre (Figure 14 and 15) have focused on stubble and seeding management to improve microclimate and seed yield. Specifically, they researched stubble retention of various heights to measure the effect on soil moisture retention. Tall stubbles in various crops reduced water loss from wind and evaporation.

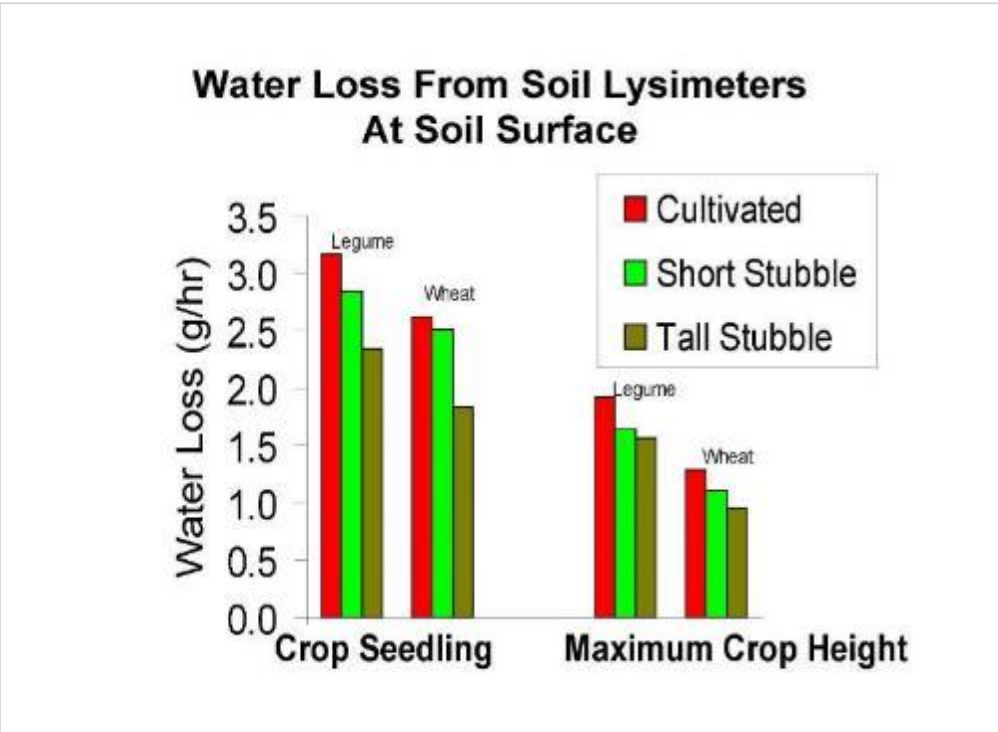

Figure 12: Evaporation loss between various stubble treatments at Swift Current Source: Cutforth, H. (Supplied August 2014)

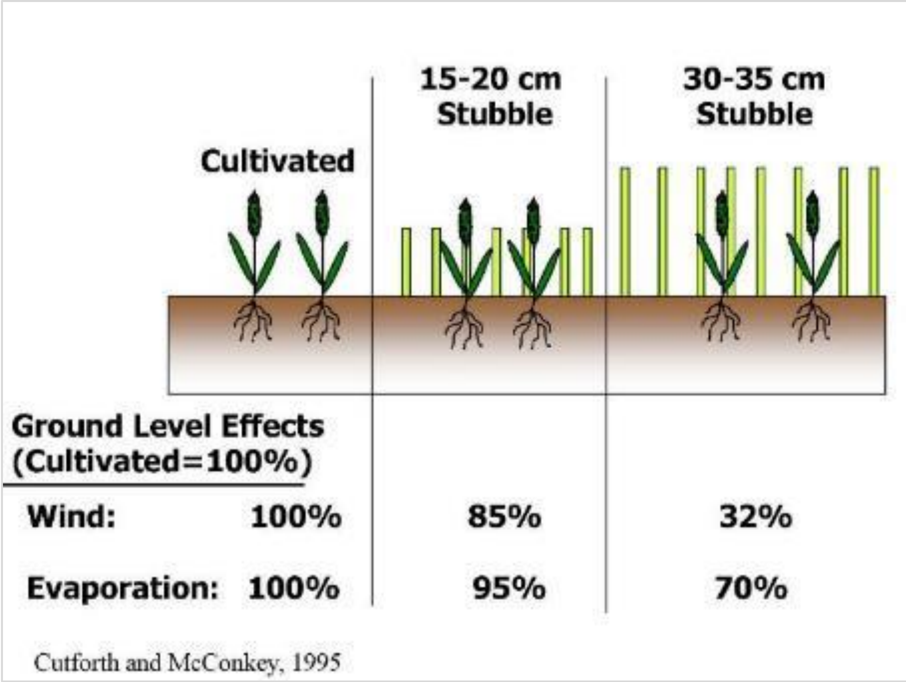

Figure 13: Effect of stubble height on wind and evaporation at Swift Current Source: Cutforth, H. (Supplied August 2014)

One way to increase crop stubble height from the cereal harvesting process is to use a Shelbourne stripper header that attaches to a combine harvester. The British-made Shelbourne front comb utilises fast rotating fingers to pluck the heads from the stalk and was originally designed for harvesting green peas, as shown in Figure 16. The stripper front removes the heads only, thus leaving a large percentage of the straw at almost full length attached to the ground as shown in Figure 17. This provides heavy soil cover for soil health and moisture retention.

Figure 14: Shelbourne Reynolds Stripper front in the UK. Source: Gillett, N. (September 2014)

Figure 15: Harvesting with a stripper front in the Palouse, Washington State, USA. Source: Gillett, N. (September 2014)

To handle increased residue levels after harvest requires specialised seeding machinery. A disc seeding machine or hybrid is needed to handle the high stubble loading. Whilst completing the research, the author considered this maximum stubble retention system to be a missing piece of the puzzle for improving germination issues in the EWB.

In the Pacific North West of Washington State (PNW) New Zealand-made Cross-Slot seed drills are common, as show in Figure 18. These are a hybrid drill with a leading cutting disc and a blade either side for seed and fertiliser and handle residue with ease. The author was informed that current hybrid seed drills are relatively high maintenance and will create inefficiencies on large scale farms where large hectares are seeded per drill is the norm. In addition, stripper fronts have higher grain losses in lighter crops below 1.5t/ha, common in the EWB compared to draper or fixed platform headers. Further investigation is required before implementation in the EWB.

Figure 16: The author in PNW with a hybrid seed drill and a New Zealand made Cross-Slot assembly on a locally produced Ag Pro frame. Source: Gillett, N. (September 2014)

2.7 Ability to place seed into moisture at depth

Fallow is common practice in the PNW, with a typical farm cycle being 50% fallow and 50% crop. A fallow is when a field is left out of a cropping cycle and weeds which germinate during this time controlled either by chemical or mechanical means. This allows for retention of moisture for the following crop cycle. A majority of fallow is mechanical in PNW where tilled, soft soil remains on the surface known as a “dust mulch”. This works well for moisture retention due to slowing the capillary rise of moisture to the surface where it is lost to evaporation, although the soil is very prone to erosion.

The development of the deep-furrow split-packer John Deere HZ drill in the mid 1960’s was a seeding revolution (Figure 19). Still widely used today it has assisted germination by being able to seed deep into the soil profile and push drier top soil into the interrow. Row spacing is 400mm primarily for furrow definition and not to handle high stubble residue. Common seed depth is 125-150mm. There are now new deep furrow drill variants under evaluation as in Figure 20, that address the issues with high residue levels that are more suited to conservation tillage and stubble retention.

Figure 17: Deep-furrow split-packer John Deere HZ drill, Ritzville, WA, USA. Source: Gillett, N. (September 2014)

Figure 18: Fexicoil PTX drill with moisture seeking attachments. Source: Gillett, N. (September 2014)

In the EWB, utilising technologically-advanced machinery to enable improved seeding depths for seed to seek moisture has merit due to the lack of surface moisture (0-100mm) often encountered at seeding. The challenge for farmers in the EWB is developing a system that jointly encourages deep seeding along with no-till and maximum stubble retention. The reason for this is deep planting requires more aggressive action to scrape away top soil to allow placement of seed into the moist deeper layer, as shown in Figure 21. Most cereals in EWB are currently sown no deeper than 75mm.

Figure 19: The deep furrow. Source: Gillett, N. (September 2014)

By retaining more residue this will enhance moisture retention and infiltration and improve overall soil health. This will take time in the EWB however more moisture from less rain is required. Finding a robust seeding system that handles taller crop residues and can also seed deep into the moisture band will be the key to a successful system.

2.8 Early sowing

Low rainfall cropping farmers sow early to maximise water use efficiency. Sowing on time or early can mean a large portion of a cropping program is seeded prior to opening rains, despite little indication of potential from the weather conditions ahead. In addition, drought stress at grain fill is also typical for the EWB short growing season.

Advantages of early sowing include:

- Crops established early in warm conditions are more vigorous leading to deeper root exploration and increased weed competition.
- Crops that flower earlier will have a longer grain filling period and can handle hot and dry finishes better.
- Reduced risk of a number of root diseases; such as crown rot, a disease caused by the fungus Fusarium pseudograminearum, resulting in less yield loss than in later sown crops.
- Logistical benefits. With the high ownership cost of machinery, it is imperative to increase hectares/machine to reduce cost/ha. To finish seeding by a chosen date the seeding operation may have to start earlier to allow this and gain benefits from better machinery utilisation.

Disadvantages of early sowing include:

- Dry sowing is at more risk of a false break, especially on heavier soil types.
- Varieties which flower earlier are more at risk of frost damage in frost-prone areas. Risk versus reward needs to be weighed up.
- Increased biomass from a longer vegetative growth period increases haying-off (premature ripening) risk due to crop exhausting available moisture in the spring.
- Sowing early can exacerbate diseases like Yellow leaf spot. Microscopic ascospores from stubble residue are highly active after the first rains or moisture from dew. These can spread quickly with plants hosts like an early germinated wheat crop.
- No opportunity for pre-seeding chemical or mechanical weed control if crop sown dry, complete reliance on in-crop weed control is required which increases the chance of weed problems and poor establishment

Dry seeding is not only adopted in the EWB but in other low rainfall areas around the world. Mike and Corey Nichols farm in the Horse Heaven Hills in Washington State, near the Oregon border. With less than 150mm annual rainfall and a wheat yield of 18 bushels (1.2t/ha) this is regarded as marginal for growing crops. With a 50% fallow system – cropping one year and fallow the next – and seeding via set dates, this has enabled them to be successful with their operation.

Figure 20: Extracting profits from low rainfall and yield with Mike and Corey Nichols. Source: Gillett, N. (September 2014).

The author observed worldwide that the practice of seeding on a set date is adopted more in marginal lower rainfall environments whereas seeding opportunities are driven by soil moisture in the higher rainfall zones. Early sowing success in a low rainfall environment on the other side of the world reinforces the value of what is now widely practiced in the EWB. The author has moved towards a mid-May seeding finish date recently from early June. Greater yield potential is the aim.

2.9 Understanding paddock variability and using variable rate technology

The ability to map crop yield data in paddocks with technology on modern harvesters gives the ability to study spatial paddock performance via global position systems (GPS). Once data has been collected over collective seasons, sites can be assessed for yield variability and yield potential zones identified for future management.

Reasons for yield performance variability can be, but not limited to:

- Soil nutrition.
- Soil PH.
- Water holding ability of soil
- Water releasable properties of soil.
- Leaching potential of minerals.
- Physical barriers to limit root depth (compaction and shallow soils).
- Chemical barriers to root growth (boron toxicity).
- Salinity.
- Frost.
- Waterlogging.
- Soil structure.
- Paddock elevation e.g. susceptibility to frost

The variables above can be tested, assessed or observed and management practices used to rectify low yielding zones. For example, fertiliser inputs can then be matched to yield potential zones at seeding, spreading or spraying rather than using a blanket rate of product. This is known as Variable Rate Technology (VRT). This can create savings thought more efficient use of inputs and achieve better yield potential and sustainability if combined with the right agronomy practices.

The author regularly uses yield maps to develop VRT prescription maps. Figure 23 to 25 are of wheat yields at the authors property across three different seasons.

- 2007- “Poor season” 118mm GS and 189mm total.

- 2013- “Average season” 184mm GS and 285mm total.
- 2008- “Good season” 223mm GS and 307mm total.

The accompanying yield data is summarised in Table 3 across the three different seasons.

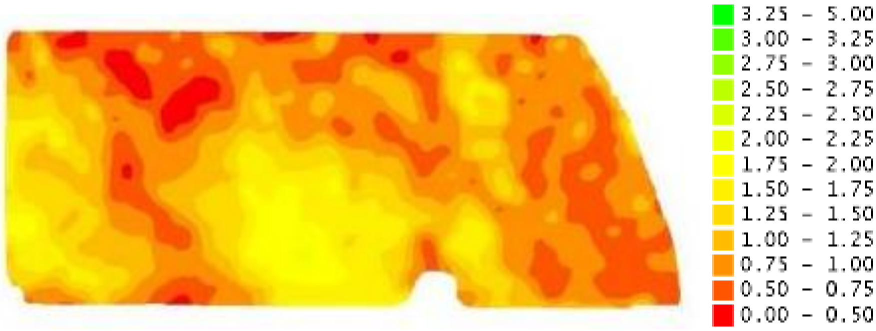

Figure 21: Yield map, M9 “poor season” – 2007. Source: Gillett, N. (December 2016)

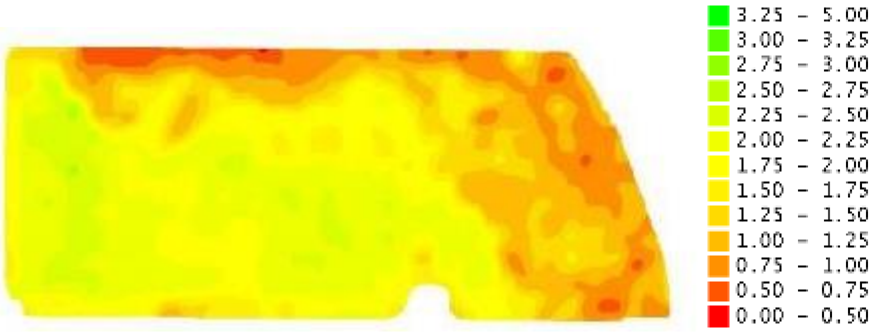

Figure 22: Yield map, M9 average season – 2013. Source: Gillett, N. (December 2016)

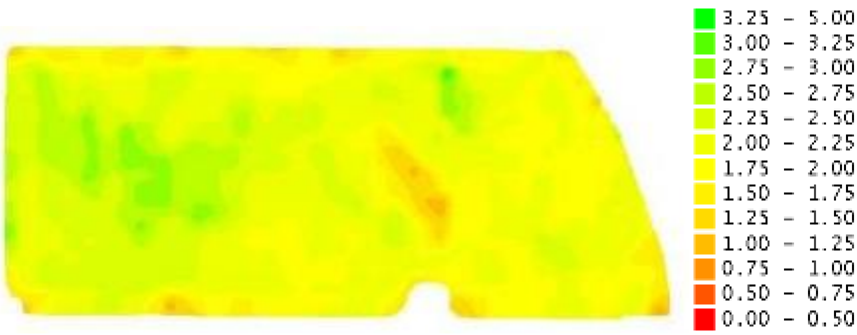

Figure 23: Yield map, M9 good season – 2008. Source: Gillett, N. (December 2016)

Paddock Malkana 9	Avg wheat yield (T/ha)	Yield variation (T/ha)	Paddock zones by yield	crop ha in zone
Poor Season (2007)	1.05	0.00-2.00	Low 0-1 t/ha	47.81
(Image 4)			Med 1-2 t/ha	42.52
			High 2-3 t/ha	0.14
			Total ha	90.47
Average Season (2013)	1.65	0.50-2.50	Low 0-1 t/ha	11.55
(Image 27)			Med 1-2 t/ha	50.02
			High 2-3 t/ha	28.9
			Total ha	90.47
Good Season (2008)	2.12	1.25-3.00	Low 0-1 t/ha	0
(Image 5)			Med 1-2 t/ha	31.03
			High 2-3 t/ha	59.44
			Total ha	90.47

Table 3: Paddock M9 variability summary. Source: Gillett, N.

As part of the research, three yield maps were used to generate a VRT zone map, based on typical seasonal conditions in Bencubbin, WA, for a "best bet" scenario as shown in Figure 26.

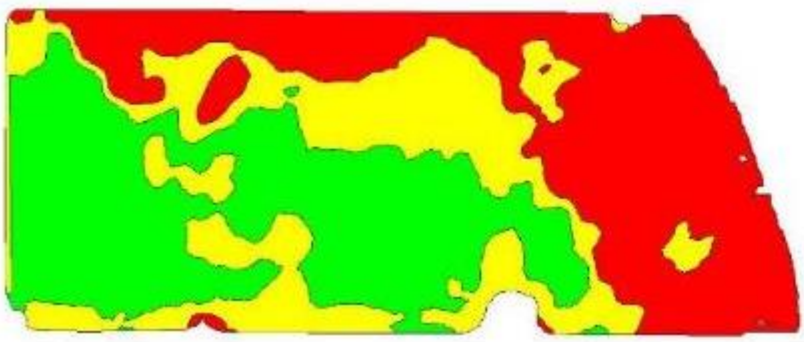

Figure 24: VRT zones for an average season. Source: Gillett, N. (December 2016)

In conjunction with Table 4 below, this map is based on low (red) and inconsistent (yellow) zones receiving less fertiliser and seed than the more consistent (green) higher yield zones which received more. The objective was to use the same amount of inputs as a blanket application but being specifically targeted to receive the best financial return and long-term production viability.

Red zone. Bottom third of paddock yield. 30.00 ha	High Phosphorous levels present- 40ppm (cowell) Low maintenance rates required.
	Yields well in wet years, below paddock average in average and poor seasons.
	Strong clay-based soil
	Aim for 1t/ha yield potential
Yellow zone. Middle third of paddock yield. 30.00 ha	Sufficient Phosphorous, 25ppm (cowell)
	Yields in all years
	Clay-loam based soil
	Aim for 1.4t/ha yield potential
	Mod to low pH so will need 1t/ha lime sand application
Green zone. Top third of paddock yield. 30.47 ha	Sufficient to decreasing Phosphorous, 20ppm (cowell) indicates consistent higher yields removing more phosphorous than applied via previous blanket rates.
	Yields well every year
	Loam based soil
	Aim for 2t/ha yield potential
	Low pH so will need 2t/ha lime sand application

Table 4: Paddock information used to develop the VRT zones indicated in Figure 26. Source: Gillett, N. (December 2016)

Total products used for the paddock, as shown in Table 5, via both application methods are similar in this example. Therefore, immediate financial savings have not been made. The strategy is to use higher rates in the green zone for higher yield potential and address further nutritional decline and soil health whilst maintaining and building its productive capacity into the future with the red and yellow zones. With a conservative mindset and concerns about season potential, additional nitrogen other than what is supplied from starter fertiliser can be applied later in the season on the higher potential zones if season permits. This reduces financial risk.

		Blanket Rates per ha				**Variable rate application**			
	Zone ha	Phosphorous Kg	Nitrogen Kg	Seed kg	limesand t	Phosphorous Kg	Nitrogen Kg	Seed kg	limesand t
High Yield potential	30.00	6.00	20.00	60.00	1.00	9.00	30.00	65.00	2.00
Med yield potential	30.00	6.00	20.00	60.00	1.00	6.00	20.00	55.00	1.00
Low yield potential	30.47	6.00	20.00	60.00	1.00	3.00	10.00	45.00	0.00
Totals	90.47	542.82	1809.40	5428.20	90.47	541.41	1804.70	4971.15	90.00

Table 5: Product used - blanket application vs VRT. Source. Gillett, N. (January 2017)

It is imperative for EWB farmers to build intimate knowledge of productive capabilities of their paddocks. By gathering spatial yield data from harvesting this further allows opportunities for assessment and analysis. By utilising harvester yield maps EWB farmers can lower input costs whilst maintaining the productive capabilities of high yielding paddock zones.

Chapter 3: Hydrophilic Polymers

Can artificial moisture attracting compounds be effective and efficient in ensuring adequately available moisture to enhance the seed germination process? Used widely in everyday products from absorbent nappies to gels for flower preservation, they vary in form, hygroscopic strength and toxicity.

Solvay International Chemical Group (Brussels, Belgium) is a world leader in polymers. They are developing a suite of hydrophilic polymers which are natural sugar-based compounds that are safe to the environment. GSB is a seed coating “agropolymer” which create a gradient of hydrophilicity that attracts water and nutrients towards the seed through capillary forces. GSB product information states significant yield improvement in simulated low moisture situations, as shown in Figure 27. Trial data suggests root length increased by 55% seed weight by 10% and ultimately yield by 10% (Smith. D, Solvay Australia). The cost of this product is quite secretive, suggesting a profit share arrangement from its performance. It is unknown how suitable this product is for use with low yielding crops in the EWB of WA where minimising costs is imperative.

Bean	4 Ha = 10 Acre Field Trials	Irrigation 30 mm	Irrigation 15 mm	
Root Length	0.2% GSB		26.4	+55%
cm	Control	17.0	16.4	- 3 %
PMG (g)	0.2% GSB		560.2	+10%
Weight of 1000 seed	Control	509.1	457.4	- 10 %
Yield	0.2% GSB		110.0	+10%
index	Control	100.0	78.9	- 21 %

Figure 25: Solvay GSB polymer providing resistance to moisture stress in beans. Source: Smith. D, Solvay Australia. (July 2014)

Another polymer called WR30 also produced by Solvay and scientifically similar to GSB is a free-flowing powder and readily dispersible in water allowing it to be used through common liquid fertiliser injection systems. When WR30 is applied to soil in a petri dish, water flow is directed towards the zones treated with the biopolymer at 50ppm, as shown in Figure 28. This is the left-hand side of the red line showing its strong magnetic like attraction to water.

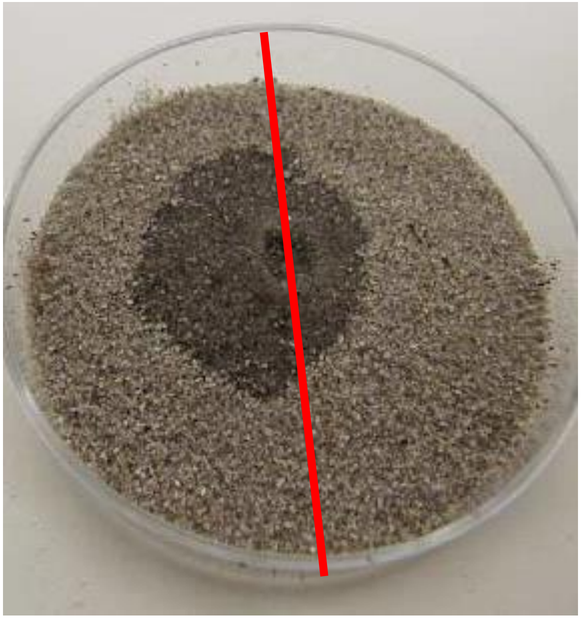

Figure 26: WR 30 seed zone applied polymer. Source: Smith. D, Solvay Australia (July 2014)

WR30 can also increase soil water holding capacity by reducing the effects of gravitational drainage, as shown in Figure 29. This could hold moisture for longer in the seed zone allowing better germination and may have value in the EWB. The applicability of this product is unknown as the costs have not been detailed by the company.

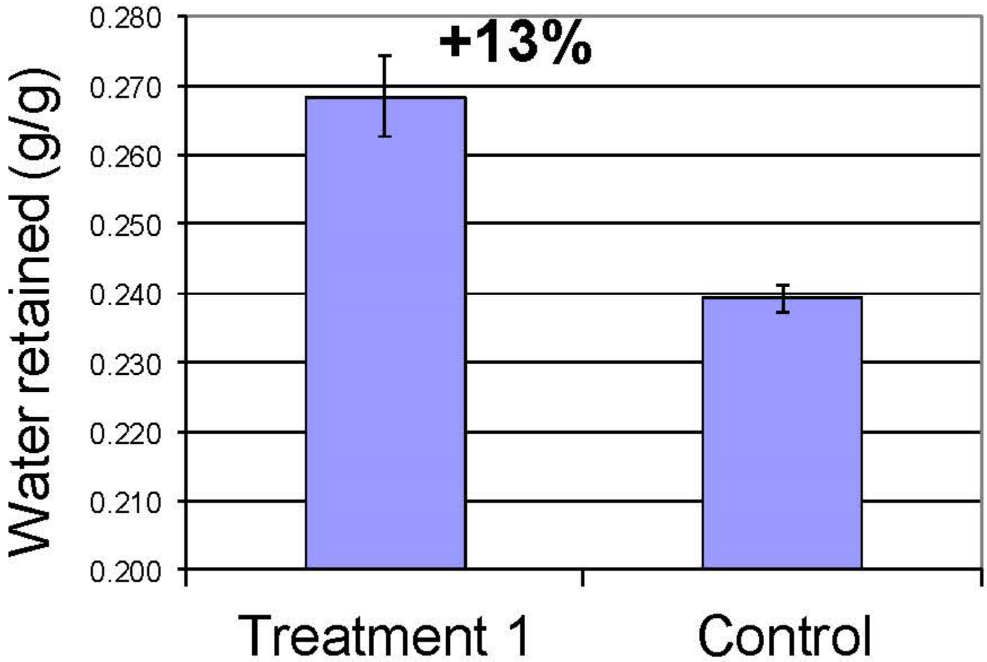

Figure 27: Water holding capacity under gravitational drainage. Source: Smith. D, Solvay Australia. (July 2014)

Products applied to the soil surface

The CSIRO in Australia have developed a spray-on, biodegradable polymer membrane to reduce evaporation from the soil-bed (Figure 30). This polymer will act like plastic sheeting on the ground surface. Trials suggest a 70% reduction in water loss or similar yields with 28% less applied rainfall, as shown in Figure 31. Cost is still yet to be determined and initial trials suggest a large product rate is required per hectare to have the desired effect. This may limit its use in broadacre cropping systems. However, yield results from this trial further reinforces the value of reducing soil moisture loss in the EWB. This product is currently being evaluated in a project by GRDC in the EWB with results to be released in early 2018.

Potential for polymer adoption in the EWB cropping system will be determined by ease of use and most importantly return on dollars invested. More trial data is required in this environment as it is yet to reach a commercial phase.

Figure 28: CSIRO polymer film. Source: Bristow, Dr K. CSIRO (February 2015)

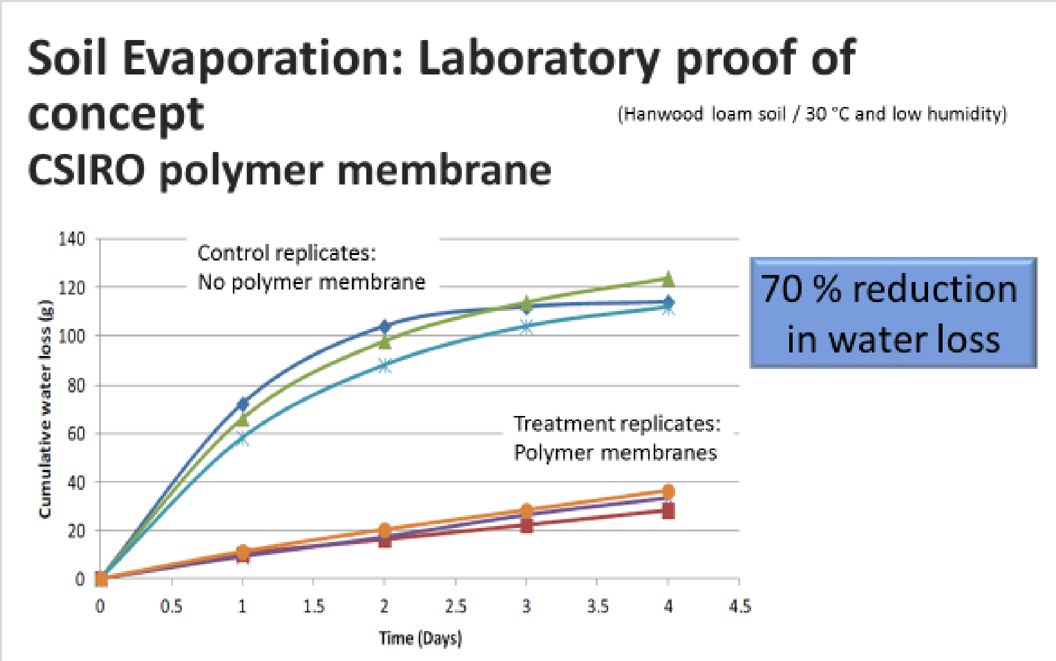

Figure 29: CSIRO polymer membrane. Source: Bristow, Dr K. CSIRO (February 2015)

Chapter 4: Crop breeding

4.1 The future

The incorporation of a suite of desirable breeding traits into new crop varieties will help in the short to long-term. With "an explosion of sophisticated new pre-breeding technologies" (Christopher et al 2017) the following list outlines desirable traits that would benefit producers in low rainfall cropping zones:

- Longer coleoptile length and strength will be critical for germination from depth in marginal moisture situations. Sowing deep will distance the seed from a fast-drying topsoil. Long coleoptile genetics are here in Australia now and Greg Rebetzke, CSIRO has successfully incorporated this trait into commercial wheat varieties like Wyalkatchem (Bred by Intergrain, released 2001).
- Early vigour selection will improve water use efficiency by accessing moisture and nutrients from fast, exploratory root growth.
- "Stay green" phenotyping retains green leaf area longer after flowering, prolonging carbon assimilation during the grain filling period producing greater yield, particularly under terminal drought (Christopher et al 2014). Current GRDC-led research has looked for genetic clues in the root systems to fully understand the underlying mechanisms.
- Commercial hybridisation of wheat varieties is now in progress, further developments will occur in parental selection which should see hybrids combining high yield, quality and disease resistance.

4.2 Coleoptile length and germination

The coleoptile is a pointed protective sheath covering the emerging shoot in monocots and enables the shoot to push through the soil. Longer and stronger coleoptiles are required for deeper sowing to chase moisture and enable acceptable emergence in marginal conditions. The introduction of high-yielding semi-dwarf wheat cultivars in the early 1960s spawned the "green revolution". Height reduction in semi-dwarf cultivars was due to mutations in *Rht-B1* (*Rht1*) or *Rht-D1* (*Rht2*) genes (Japanese dwarfing genes). Semi-dwarf wheat cultivars are naturally higher yielding due to less energy being used for biomass and more transferred into grain production. The reduced cell-size associated with *Rht-B1b* and *Rht-D1b* also decreases coleoptile length and seedling leaf area, which reduces seedling vigour and compromises emergence from deeper sowing (Rebetzke et al 1999). Alternatively, the *Rht8* gene has been identified to reduce plant height without reducing coleoptile length and thus have less negative effect on emergence (Mohan et. al 2013). This longer and stronger coleoptile trait would be highly valued in the EWB.

Emergence from deep planting is particularly important in the low-precipitation dryland regions of the world, such as the inland PNW where it is critical for prompt establishment prior to winter snowfall. It is common for wheat to be planted as deep as 200mm with deep-furrow drills and seedlings must emerge through 150mm or more soil cover, as shown in Figure 32.

Figure 30: Long coleoptile triticale emerging from depth. Ritzville, Washington State, USA. Source: Gillett, N. (September 2014)

A leading university in the PNW, Washington State University (WSU) has been conducting trials on a collection of 662 carefully selected wheat cultivars from around the world. This represents a full range of variation in traits allowing them to gain improved understanding of the relationship between coleoptile length and emergence from deep planting depths. Seeds were sown 150mm below the soil surface and the soil covering the seed was 125mm. The results from their extensive study explains only 28% of the variability for seedling emergence was related to coleoptile length. Contradictory to earlier reports suggesting a linear relationship between coleoptile length and emergence suggesting more variables like coleoptile strength are at play.

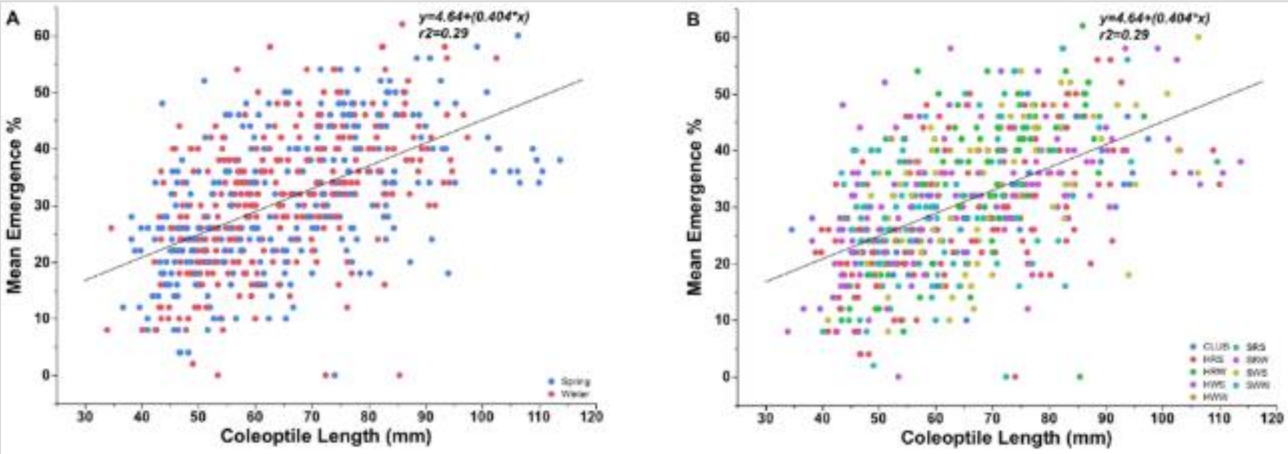

Figure 31: Wheat Seedling Emergence from deep planting depths and its relationship with coleoptile length. Source: Amita Mohan, William F. Schillinger, Kulvinder S. Gill. (Published September 2013) http://dx.doi.org/10.1371/journal.pone.0073314

4.3 Hybrid wheat

The floral biology of wheat has to be modified to produce the hybrid wheat seed. Wheat is naturally self-pollinating and fertilisation takes place in a self-contained environment within the glumes enclosing the pistils and stamens (Figure 34). Hybridisation is performed manually – removal of stamens (male part of the flower) – pollen is applied to the pistil (female part) of a plant with a different genetic background during the breeding process (Saaten-Union, 2012).

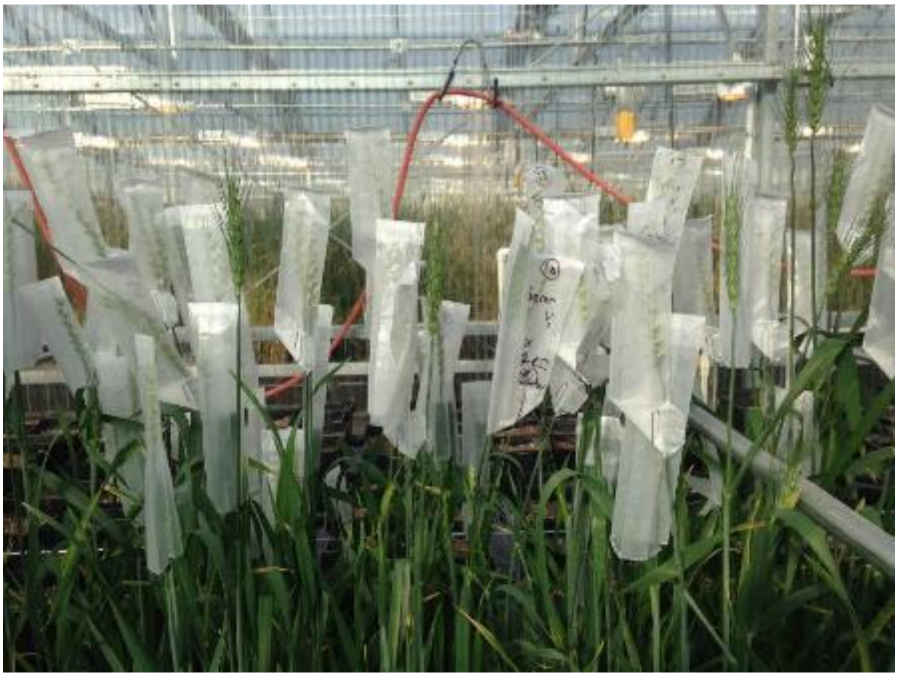

Figure 32: Hybrid wheat at Syngenta breeding facility, Junction City, KS, USA. Source: Gillett, N. (September 2014)

Although heterosis (hybrid vigour) is weaker in self-pollinating wheat, than in plants like maize, some hybrid wheats can increase yield by more than 20% when compared to the average of their parents, and even more in stressful conditions. The thousand-seed grain weight, tiller count and seeds/head are higher in hybrid wheat and are the components responsible for yield gain. The grain filling duration is the same, but the grain filling rate is faster for hybrids than for conventional varieties.

Yield stability is the main advantage with hybrid wheat under a wide range of environmental conditions. Hybrids tolerate periods of moisture stress, temperature variation and insect damage greater than conventionally bred lines. An explanation lies in the vigour of the hybrid wheat root system where numerous trials have demonstrated that the hybrid develops a far more powerful root system than its parents.

The economic threshold for the acceptance of hybrid wheat is a complex function of a number of factors beyond the additional quantity of grain produced by the hybrid. These factors include:

- Hybrid advantage, such as yield stability, pest protection and agronomic traits important in any specific hybrid versus cultivar comparison.
- Average purchase price of hybrid seed versus varietal seed.
- Anticipated commodity price of grain, or other market factors.
- Expected return on the hybrid seed investment by the grower.
- Seeding rate of the hybrid versus the cultivar.
- Risk of crop failure due to natural disasters.
- Potential scale up from breeders given the multiplication ratio is only 1 seed to produce 60 seeds compared to 600 seeds in canola. This means a greater land area for breeding is required.

The future commercialisation of hybrid wheats in Australia is unknown and the cost of seed compared to the returns may limit the uptake of hybrid wheats in low yielding farming areas. Nevertheless, hybrids offer greater yield stability within stressful environments and germination vigour and this is a requirement for the EWB.

Conclusion

The EWB climate and soil moisture holding characteristics are unique on a world stage. Many hours and kilometres were exhausted during this study whilst chasing the holy grail of grain farming and improving germination in marginal conditions. There were no simple answers.

Improvements will be incremental, driven by a grower`s need and value placed on the germination challenge. Specific findings from this study include:

- Measurement of localised and deep stored moisture to enable better knowledge of germination and management decisions.
- Further refinement of no-till cropping systems in an environment of low biomass production.
- Minor adjustments to seeding machinery for moisture seeking are possible with high breakout tines to enable moisture seeking to improve germination.
- Innovative seed dressings and polymers to assist germination are futuristic and due to the costs may never be widely adopted in the EWB, although the technology needs to be assessed in trials to fully appreciate their interaction.
- The merits of livestock in the cropping system need to be assessed on an individual business basis to understand if they are a truly synergistic fit. Loss of stubble cover, compaction and poor weed control in the pasture year can all impact crop potential.
- The incorporation of a suite of desirable breeding traits into new crop varieties will help in the medium-term providing commercial breeders can ensure financial return. Traits important to the EWB include:
    - Longer coleoptile length and strength will be critical for germination from depth in marginal moisture situations. Early vigour selection will improve water use efficiency by accessing moisture and nutrients from fast, exploratory root growth.
    - “Stay green” phenotyping retains green leaf area longer after flowering.
    - Commercial hybridisation of wheat varieties is now in progress, further developments will occur in parental selection which should see hybrids combining high yield, quality and disease resistance.

Cropping in the EWB is a risky business. Risk can equal reward but with an inflationary cost base and grain pricing not being interconnected, the downside of poor seasons is immense. On the flip side, a run of successful seasons can deliver large cash surpluses. Seasonal potential cannot be fully known until October because one rainfall event can quickly change potential. Early dry conditions in the seeding period does not mean the remainder of the season will be dry. EWB farmers need to have seed in the ground early to have a chance, with cost control and agronomic nous their only insurance policy of a decent crop.

Most importantly of all is personal well-being to enable the best results. Maintain a positive mindset, converse with likeminded peers openly, focus on great results – let this drive you and aim to enjoy the challenge. Farming in the EWB will always be variable but this provides opportunity.

Recommendations

- Any incremental improvement to soil moisture utilisation will have a profound effect on financial sustainability.
- Gaining superior knowledge of the germination process and moisture retention of soils will enable growers to understand and tweak management practices.
- As an industry, it is important to demand desirable breeding traits as they can be utilised through all rainfall zones without disadvantage and helps seed emergence in any sub-optimal conditions.
- Timely germination could triple yields if accessible soil moisture is utilised.
- Minor adjustments to seeding machinery for moisture seeking are possible and the quest for soil improvements for reducing moisture loss should start today.
- It is recommended that innovative seed dressings and polymer technology be assessed in trials to fully appreciate their interaction to assist with germination.
- Varying input costs through VRT to best match yield potential and reducing the breakeven costs of the operation are a simple solution to financial success.
- Minimising downside loss in poor seasons and capturing every last cent from the good seasons are critical.

References

Anderson, W.K. and Garlinge, J.R. (2000) The Wheat Book. Bulletin 4433. Pages 133-136. Department of Agriculture, Western Australia.

Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES) 2017, Agricultural commodities: March quarter 2017. agriculture.gov.au/abares/publications.

Abrecht, D and Robertson, M. Events defining the onset of the growing season in a Mediterranean environment. Research paper. Department of Agriculture and Food Western Australia and CSIRO Ecosystem Sciences and Climate Adaptation Flagship.

Agvise Management Consultants 2015 Benchmarking Survey (Client only publication)

Barrett, J. (January 2017) Personal communication. Celsius Pro. Sydney. NSW.

Biddulph, B. Curtis, B. Ellis, S and Shackley, B. DAFWA; Eagles, H. University of Adelaide; Eastwood, R. AGT; Hollaway, G. Victorian DPI; Hunt, J. CSIRO; Martin, P and Simpfendorfer, S. NSW I&I; McClelland, T. BCG; and Poole, N. Foundation for Arable Research. https://grdc.com.au/uploads/documents/GRDC_FS_TimeOfSowing_West.pdf
Time of sowing fact sheet. March 2011. Grains Research & Development Corporation. Produced by www.coretext.com.au

BCW Agriculture Ltd. Hybrid wheat technology booklet
www.bcwagric.co.uk/download/31

Christopher, Dr J, Veyradier, M. Harvey, G. Fletcher, S. Borrell, Dr A. and Chenu, Dr K. (05.03.2014) Stay green in wheat has potential to improve yield independently of root traits. Queensland Alliance for Agricultural and Food Innovation (QAAFI) U https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2014/03/Stay-green-in-wheat-has-potential-to-improve-yield-independently-of-root-traitsniversity of Queensland. GRDC code: UQ00057; UQ00068

Conversation, The. Australia's 'five strong pillar economy': agriculture
April 27, 2015 5.31am AEST
http://theconversation.com/australias-five-strong-pillar-economy-agriculture-40388

Cutforth, H. and McConkey, B. (Nov 5 2009)
Stubble Height, Microclimate, and Crop Yield in the Semiarid Prairie
A presentation file supplied. Semi-Arid Research Station, Swift Current, Canada.

Guthrie, M. Evans, F. and Bowran, D. (GIWA crop report 13th June 2014 and 5th December 2014) The influence of climate change on Western Australian agriculture.
Department of Agriculture and Food, WA.

Hall, B. Icon Agriculture. Ferguson, M. Department of Agriculture and Food Western Australia.
Curnow, M. Department of Agriculture and Food Western Australia
Thompson, A. Department of Agriculture and Food Western Australia (2012)
Sheep – the simple guide, © Sheep CRC & Department of Agriculture and Food Western Australia, 2012
http://www.sheepcrc.org.au/files/pages/information/publications/sheep-the-simple-guide-to-making-more-money-with-less-work/Sheep_the_Simple_Guide_Cereal_Sheep_Zone_version_for_web.pdf

Hunt, J. CSIRO (09.02.2011) Summer fallow management
https://grdc.com.au/Research-and-Development/GRDC-Update-Papers/2011/02/Summer-fallow-management

Horton, J. Strategis Partners. (19th May 2015) ABC rural report.
http://www.abc.net.au/news/2015-05-19/farm-consultant-questions-merit-of-multi-peril-crop-insurance/6480796

Invest in Australia. Agriculture Australia.
http://www.investinaustralia.com/industry/agriculture/agriculture-australia

Kirk, G. Director of Planfarm Pty Ltd. How to Farm Profitably in the Eastern Wheatbelt of Western Australia. (2014) A GRDC funded project investigating what can be done to improve the profitability of farming in the low rainfall eastern wheatbelt region of WA.

Llewellyn, Dr R and D'Emden, F. H. (February 2010) Adoption of no-till cropping practices in Australian grain growing regions. GRDC Project Code: SAN00013
Report for SA No-till Farmers Association and CAAANZ

Mohan, A. Schillinger, W.F. Gill, K.S. (September 3, 2013) Washington State University, the Washington Grain Commission, and the National Science Foundation.
Wheat Seedling Emergence from Deep Planting Depths and Its Relationship with Coleoptile Length.
http://dx.doi.org/10.1371/journal.pone.0073314

Saaten-Union. (June 2012) Hybrid technology: the wheat of the future. Advertising leaflet.
www.bcwagric.co.uk/download/31

Sperlings. Best places. Climate in Palouse Washington.
http://www.bestplaces.net/climate/city/washington/palouse

Williams, M. (8/1/2016) Summer weed control-saving soil nitrogen and water to boost crop profits. Cox Inall Communications. GRDC
https://grdc.com.au/Media-Centre/GRDC-E-Newsletters/Paddock-Practices/Summer-weed-control-saving-soil-nitrogen-and-water-to-boost-crop-profits

Wuest, S. B. Lutcher L. K. (28 Mar. 2012) Soil Water Potential Requirement for Germination of Winter Wheat. Soil Science Society of America Journal.USDA-ARS Columbia Plateau Conserv. Res. Cente. Dep. of Crop and Soil Science

Oregon State Univ.
https://www.ars.usda.gov/ARSUserFiles/6233/soilWaterPotential.pdf

Young, D.L., Hinman, H.R., Schillinger, W.F. (2000) Farm Business Management Reports EB1907 Economics of winter wheat-summer fallow vs continuous no-till spring wheat in the horse heaven hills, Washington. WSU extension.
http://www.pnw-winderosion.wsu.edu/Docs/Publications/01%20pubs/Youngeconomics.pdf

Plain English Compendium Summary

Project Title:	**Innovative ways of improving crop germination and yield in a drying climate**
Nuffield Australia Project No.:	1402
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Objectives	• To appreciate the local climatic conditions in the eastern central wheatbelt of Western Australia • To discover how we can improve financial resilience by improving our cropping knowledge and systems based around crop establishment. • To investigate the moisture requirements for crop germination and spatial variance. • To present a collection of ideas, techniques and innovation for adaption now and into the future for implementation into dryland cropping systems and risk mitigation.
Background	Dry seasons have become more common in the EWB of Western Australia. This poses a significant challenge with crop establishment and crop yield. Ultimately having a significant effect on financial performance.
Research	Meetings with university professors and students to study crop germination, moisture retention and financial implications. Farmers imparted local and practical knowledge about cropping systems and best practice. Countries travelled were Canada, USA and the UK.
Outcomes	There is a collection of practical solutions available now to assist with cropping in a low moisture environment. Knowledge and incremental improvements will improve overall performance. Breeding and alternative technologies will have a role to play in the future.
Implications	Adapting to the challenge of farming in a moisture limited environment will enable prosperity for growers and the communities. Financial institutions, peak farm bodies, national researchers and the government all have a role to play to ensure this success.
Publications	A summary of this report has been presented at “Crop updates” Perth 2015, Merredin 2016, Facey Group 2016 and various grower and agronomy groups.