GRAINS RESEARCH UPDATE

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GRAINS RESEARCH & DEVELOPMENT CORPORATION

Bannockburn

Thursday 27 February

9.00am to 1.00pm

Bannockburn Cultural Centre,
27 High Street

#GRDCUpdates

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

Bannockburn GRDC Grains Research Update
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GRDC Grains Research Update
BANNOCKBURN
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Dealing with the Dry

As grain growers across Queensland and New South Wales and parts of Victoria and South Australia continue to be challenged by drought conditions, the GRDC is committed to providing access to practical agronomic advice and support to assist with on-farm decision making during tough times.

Visit our ‘Dealing with the Dry’ resource page for useful information on agronomy in dry times and tips for planning and being prepared when it does rain.

www.grdc.com.au/dealingwiththedry

GRDC
GRAINS RESEARCH & DEVELOPMENT CORPORATION

P Level 4 | 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604 **T** +61 2 6166 4500 **F** +61 2 6166 4599
E grdc@grdc.com.au @theGRDC

Program

9.00 am	**Announcements**	***Tim Bateman,*** *ORM*
9.05 am	**GRDC welcome and update**	***GRDC representative***
9:15 am	**Breaking the big yield constraints – where to next?**	***James Hunt*** , *La Trobe University*
9:55 am	**Hitting production targets in the UK amidst a highly regulated environment**	***Keith Norman,*** *Keith Norman Consultancy Ltd, UK*
10:35 am	***Morning tea***	
11.05 am	**Crop doctor - cereal disease update**	***Grant Hollaway,*** *Agriculture Victoria*
11:45 am	**Integrating new chemistries in the field**	***Chris Preston,*** *University of Adelaide*
12.25 pm	**Addressing the yield gap in the High Rainfall Zone**	***Jon Midwood,*** *SFS &* ***Keith Norman,*** *Keith Norman Consultancy Ltd, UK*
1.05 pm	***Close and evaluation***	***Tim Bateman,*** *ORM*
1.10 pm	***Lunch***	

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Discussion paper - Busting the big yield constraints – considerations for the future?

James Hunt[1], John Kirkegaard[2], Corinne Celestina[1], Kenton Porker[3].

[1]La Trobe University; [2]CSIRO Agriculture & Food; [3]SARDI.

Keywords

- yield, cost of production, sustainable intensification.

Take home messages

- Yield increases are necessary to keep cost of production for Australian growers competitive in international markets.
- Recent yield increases associated with improved genetics and agronomy (25kg/ha/year) are struggling to counteract the yield decline due to climate change (-24 kg/ha/year), and in coming decades it is likely that yield gains need to double to maintain profits.
- Yield increases are rarely the result of a single practice or technology but occur when new and old technologies and practices combine to form improved systems that overcome a constraint to production.
- Removing nitrogen (N) limitation, allowing crop establishment in the absence of breaking rainfall and genetic tolerance to heat/drought or frost are currently major constraints to yield in Australia, and require multidisciplinary systems research to overcome them.

Why increase yield?

Cost of production ($/t) is an important factor influencing the ability of Australian grain growers to compete in export markets. One of the main ways in which Australian grain growers have been able to maintain relatively low costs of production despite declining terms of trade has been by increasing crop yield with relatively small additional overhead and input costs. While ways of reducing overhead, input and transport costs can be found (for example; through economies of scale), yield increases are still an important way in which cost of production will be kept at an internationally competitive value in the future. Yield increases are also necessary to meet the goals of sustainable intensification, whereby the additional food required for a growing global population is produced on the same area of land that is currently farmed, without the further destruction of natural ecosystems. This paper will take a brief look at where historic yield increases in Australian crop (particularly wheat) production have come from, and where we believe future gains can be made. It is based on a chapter written for the book 'Australian Agriculture in 2020', recently published by the Australian Society of Agronomy (Hunt et al. 2019a), details of which can be found in the useful resources section within this paper.

Yield, yield and yield

The concept of potential yield (PY), Figure 1, and yield gaps is crucial when looking at ways to improve yield and we follow the nomenclature of Fischer (2015). The most important definition for dryland crop production in Australia is water limited potential yield (PY_w), defined as the yield of the best cultivar under optimum management with no manageable constraints (for example; nutrient deficiency, weeds, disease) except for water supply (Figure 1). Farm yield (FY) is yield achieved by growers in their fields. The difference between FY and PY_w is termed the yield gap. Economic yield (EY) is the yield attained by growers when economically optimal practices and levels of inputs have been adopted while facing all the vagaries of weather

(Figure 1). Economic or attainable yield is typically 7 5-85 % of PY_w (van Ittersum et al. 2013). The difference between EY and FY is the exploitable yield gap. Hochman et al. (2017) describes the proportion that FY comprises of PY_w as relative yield.

The yield gap of an individual farmer is dependent on management skill and level of investment in inputs, but also incentives and capacity to achieve higher yields. Management skill means the ability of a farmer to use management and inputs to reduce the biotic (weeds, pests and diseases) and abiotic stresses (water, nutrient and temperature stress) placed on crops. The different points in Figure 1 describe different situations under which growers may or may not be achieving potential yield. The first point describes a farmer with a high level of management skill, but who under-invests in inputs and is therefore not achieving economic yield. The second point describes a farmer with a high level of skill and appropriate investment in inputs who is achieving economic yield. This farmer has closed the exploitable yield gap.

The third point describes a farmer with a high level of skill who is over investing in inputs and while exceeding economic yield, is not as profitable (due to higher costs of production) or is more exposed to risk than the second farmer. The fourth point describes a farmer who is investing enough inputs to achieve economic yield, but due to a lack of management skill has an exploitable yield gap. This farmer will obviously not be as profitable as the second farmer. To close yield gaps, the first farmer needs to invest more inputs while maintaining current level of management skill. The fourth farmer needs to improve their management while maintaining current levels of inputs. The third farmer has closed the yield gap but can afford to invest less in inputs while maintaining their management skill, thereby increasing profits.

Where do yield increases come from?

Yield of crops is determined by the interaction between genotype (G = species, cultivar), environment (E = soil and climate) and management (M = rotational position, fallow management, tillage system, sowing date, fertiliser, control of weeds, pests and disease etc.) which is referred to as G x E x M. The case of wheat (and likely other grain crops) in Australia makes an interesting case study, because the climate has deteriorated (rainfall decreased and temperature increased) and reduced water limited potential yield by 27% during the period 1990 to 2015 (Hochman et al. 2017), which is equivalent to 24kg/ha/year (Ababaei and Chenu 2020). However, growers have maintained yields by adopting improved genotypes and management practices and increased farm yield relative to water limited potential yield (closed the yield gap) at a rate of 25kg/ha/year (Hochman et al. 2017). In other words, climate change has effectively robbed the industry of the yield gains it needs to stay competitive. Of course, national averages can be deceptive; many leading growers have increased yields despite climate change by increasing water-use efficiency, and therefore, remain globally competitive. For others, there is some room to

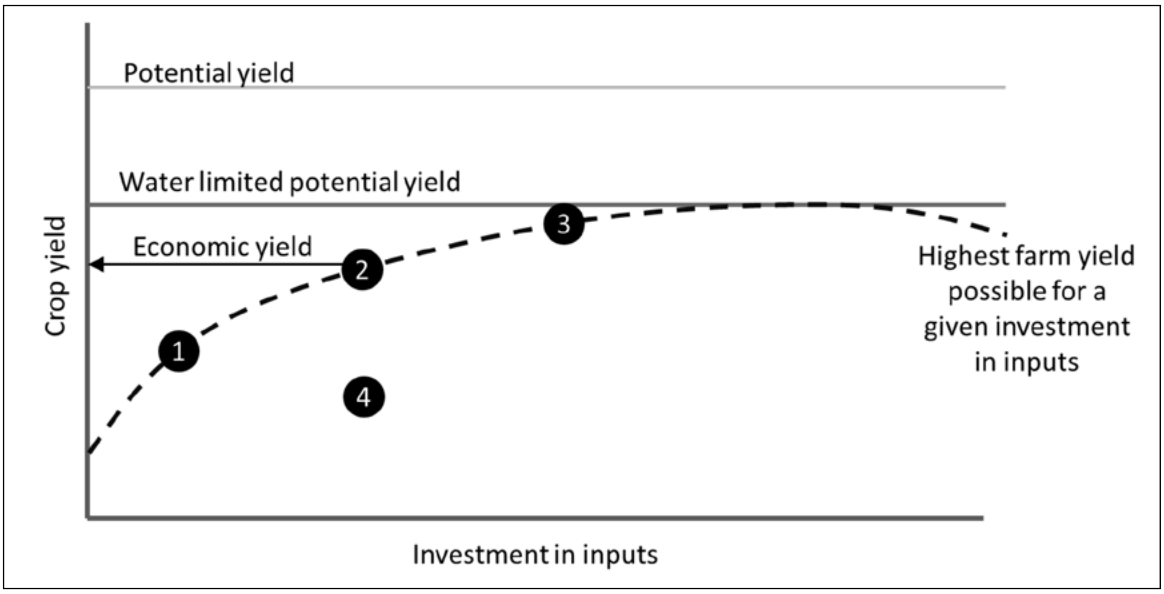

Figure 1. A graphical representation of potential yield, water limited potential yield, attainable yield and farm yield. The numbered dots represent growers with different yield gaps and different reasons for those yield gaps.

move in terms of yield gap closure. Australian wheat growers are currently achieving 55% of water limited potential yield (Hochman et al. 2017), meaning that for many growers there still exists a substantial yield gap, and yield could be further increased through adoption of best practice. Leading growers have closed the exploitable yield gap, and increased yield requires an increase in water limited potential yield (van Rees et al. 2014).

Past yield increases

Throughout history, increases in crop water productivity have rarely been attributable to an individual innovation in technology or farming practice. Increases have occurred when new and old technologies and practices combine to form improved systems that overcome a constraint to production (Kirkegaard 2019). In the example of Australian wheat production, the yield gap closure of the last 30 years has been due to many disparate technologies combining to form improved systems. The advent of non-selective knockdown herbicides (mainly glyphosate) and grass selectives drove the rapid adoption of no-till (Llewellyn et al. 2012) which improved soil water conservation and allowed earlier sowing (Stephens and Lyons 1998; Flohr et al. 2018c). Wheat was increasingly grown in rotation with broadleaf break crops (canola and pulses) rather than other cereals or weedy pastures which enhanced disease and weed management, and in the case of cereals following pulses, reduced fertiliser N requirements. Summer fallow weed control further increased soil water conservation, N accumulation and reduced root disease burdens (Hunt et al. 2013). Meanwhile breeders consistently achieved genetic yield progress of 0.5% per annum (Siddique et al. 1990; Sadras and Lawson 2011; Fischer et al. 2014; Kitonyo et al. 2017; Flohr et al. 2018b) and overcame significant biotic and abiotic constraints to production which interact with management (cereal cyst nematode, stripe rust, acidity, salinity, boron). Early sown, disease free crops responded profitably to increasing N fertiliser, applications of which tripled over the last 30 years (Angus and Grace 2017).

Future yield increases

Yield increases comparable to or exceeding those of the last 30 years are necessary to keep Australian growers competitive and to meet the goals of sustainable intensification. Fischer and Connor (2018) estimate that crop yields must increase at around 1.1% per year globally to ensure adequate food supply. While Australian growers have been able to close the yield gap by 25kg/ha/year (equivalent to 1.2% per year increase in relative yield, Hochman et al. 2017), declining rainfall and increasing temperatures have reduced water limited potential yield.

Significant yield gains in the coming decades requires a transformational change in the way we do research, development and extension. We argue that focussing research effort on developing synergistic systems that overcome current and future production constraints, combined with effective extension and adoption, will accelerate increases in yield. This will require a coordinated effort from multi-disciplinary teams, and in Hunt et al. (2019a), we describe a process of 'transformational agronomy' to achieve this. Briefly, agronomic researchers must work closely with growers and advisers to accurately define and quantify constraints to production. Solutions can then be sought and evaluated from diverse sources. Multidisciplinary teams with leadership from agronomists and close cooperation with growers and advisers will be required to achieve this. Once solutions have been evaluated and tested using a combination of crop simulation, small plot experiments and paddock-scale experiments in growers' fields, research teams need to work closely with growers and advisers to build and integrate improved, robust and adoptable farming systems that overcome the intended constraint.

Three constraints follow that we believe could be overcome with the multi-disciplinary research approach that is embodied in transformational agronomy. Indeed, if these could be achieved, we believe it would lead to transformational changes in production and profit for Australian growers. These are complex problems and will not be overcome cheaply or easily, but the pay-off from doing so would justify the investment.

Removal of N limitation

Nitrogen deficiency remains the single biggest factor contributing to the sizeable exploitable yield gap in Australian wheat production (Hochman and Horan 2018) and likely other non-legume crops (barley, oats, canola) as well. Even leading growers struggle with N management in favourable seasons (van Rees et al. 2014). At first this appears somewhat paradoxical; N management in grain crops should be extremely simple – crop requirement is well related to yield as described by the simple rule of thumb taught to all budding agronomists: 40kg/ha N per tonne of anticipated wheat yield. The supplies of N to the crop are also readily quantified – mineral N in the soil prior to sowing can be cheaply and easily measured from intact soil cores. Mineralisation is more difficult to estimate but it is possible and is self-correcting in that spring rain which leads to higher yield potential, also promotes more N mineralisation. The complexity comes in reliably estimating anticipated yields. This requires no less capability than the accurate prediction of weather several months in advance. But the difficulty arises from Australia's extremely variable rainfall. For instance, in southern NSW when growers need to make decisions regarding post-emergent N applications (typically in July-August), possible yields range from 0t/ha to 7t/ha in seasons with no stored soil water prior to sowing, and yield and N demand all depend on September and October rainfall. In addition, over-fertilisation with N can reduce both yield and grain quality through haying-off (van Herwaarden et al. 1998). N fertiliser is also a costly input and, mindful of environmental losses (Turner et al. 2012; Schwenke et al. 2014), many growers tend to err on the conservative side in their applications.

There have been consistent attempts to improve prediction of yields and to make N management more precise. This has included the use of forecast systems (Asseng et al. 2012) and decision support systems that integrate soil resources and management variables, and present likely response to N inputs in probabilistic terms (Hochman et al. 2009). While seasonal forecasts are likely to improve, they will never be perfect. Given the substantial nature of the problem, a fresh approach is required. One such solution that may work in environments with low N losses (for example; low rainfall areas with high soil water holding capacity) is the use of N fertiliser to maintain a base level of soil fertility ('N bank') sufficient to achieve water limited potential yields in the majority of growing seasons (as is currently done for phosphorus). Implementation of this strategy would need to consider the amount of mineral N in the soil profile and to adjust inputs for carry-over of previously applied N fertiliser not used by the crop. If applied appropriately at the time of rapid crop uptake, environmental losses from the 'N bank' would be low in farming systems where stubble is retained, and the majority of applied N is either taken up by the crop or immobilised into organic forms. Losses could be further reduced through use of higher efficiency N application strategies (e.g. deep and mid-row banding). Once the N banks are built, the cost of N fertiliser for growers is deferred into the season following rather with the season of high yields; this could have substantial economic value through improved cash flow and tax benefits. It may also reverse the mining of soil N that has occurred under Australian crop production since the decline in area of legume-based pastures (Angus and Grace 2017).

A multidisciplinary team is essential to test this potential solution. It requires accurate measurement of N losses and N cycling within the soil, and this requires discipline-specific expertise from within the field of soil science. In addition, economic assessment will be critical, and an investigation of management techniques to minimise possible negative effects on yield and quality from high levels of soil mineral N is required. Pre- and post-experimental crop simulation would be essential to test assumptions, identify locations and treatments that would be promising to test in the field, and extend field results over multiple sites and seasons. If found to be successful, geographic information system tools (e.g. yield and protein mapping) would allow even greater efficiencies through mapping of N removal in grain.

The 'N bank' concept has been tested using simulations at different rainfall locations in southern NSW, and were found to increase yields with minimal environmental impact (Smith et al. 2019). The first field experiment designed to test this was funded by La Trobe University and established by BCG at Curyo in 2018. The first two years of results indicate that 'N bank' strategies are equally profitable as attempting to match N inputs to seasonal yield potential using Yield Prophet® (Figure 2). More research is required to evaluate the approach across environments and to closely measure N losses.

Crop establishment in the absence of autumn rainfall

From the early breeding work of Farrer, much of the agricultural research conducted in Australia has aimed to coincide critical periods of yield determination in crops with climatically optimal conditions for growth. The cool, wet winters during which crops are grown in Southern and Western Australia often transition rapidly into hot, dry conditions with supra-optimal temperatures and limited soil water. When combined with spring frosts, this creates a reasonably narrow period during which crops must undergo their critical development phases (e.g. flowering) for yields to be maximised (Dreccer et al. 2018). While the concept of the optimum flowering window has long been known (Anderson et al. 1996), it has been the advent of computer simulation that has allowed them to be quantified for multiple locations across

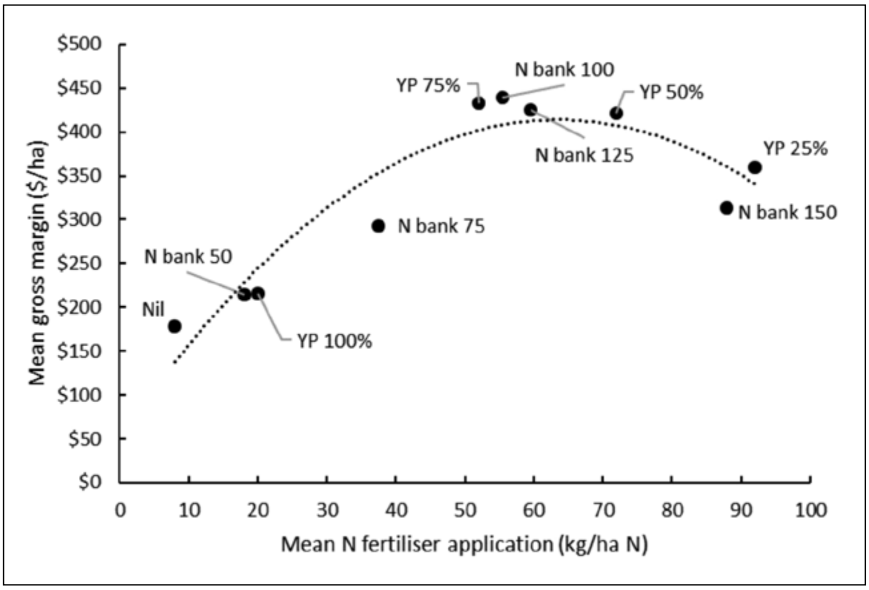

Figure 2. Mean annual N fertiliser application and mean annual gross margin 2018-2019 for different N management systems (N bank vs. Yield Prophet®) being tested in an experiment at Curyo in north west Victoria. The number following the Yield Prophet® (YP) treatments is the probability of different yield outcomes occurring at time of top-dressing in July (e.g. YP 75% targets each year the yield at which there is a 75% chance of exceeding). The numbers in the N banks treatments represent the total N supply (soil mineral N + fertiliser) that each treatment is topped-up to with N fertiliser (e.g. in the N bank 125 treatment, if 75kg/ha of soil mineral N is measured prior to sowing, it is topped up to 125kg/ha total N supply with 50kg/ha fertiliser N).

many seasons, for wheat (Flohr et al. 2017) and canola (Lilley et al. 2019) and barley (Liu et al. 2020). Shifting crop development closer toward optimal flowering periods has been the major mechanism behind many of the transformational changes in Australian crop production. This includes iconic advances such as the release of Federation wheat with its faster development pattern (Pugsley 1983), the rise of no-till which allowed much earlier sowing (Stephens and Lyons 1998), and more recent shifts to dry and early sowing (Fletcher et al. 2016; Hunt et al. 2019b).

Recent quantification of optimal flowering periods has revealed that leading growers are now coinciding critical periods with seasonal optima (Flohr et al. 2018c). The only times they do not achieve timely flowering is when they have been unable to do so due following dry autumns with insufficient soil moisture to allow seeds to germinate and emerge. Somewhat ironically, this new understanding of optimal sowing times has coincided with declining autumn rainfall (Pook et al. 2009; Cai et al. 2012) making it harder than ever for growers to achieve optimal flowering periods. This defines our second opportunity to overcome a major constraint to crop production – achieving crop establishment in the absence of favourable autumn rain. Once again, an integrated solution to this constraint demands multidisciplinary expertise led by a generalist with appreciation of the G x E x M context. Input is required from disciplines of agricultural engineering, plant physiology, genetics and soil physics.

Knowledge of the regulation of seed germination has developed greatly in recent times, yet our understanding of the mechanisms causing variation of plant establishment in the field remains limited. This is probably because most seed biology experiments are performed in laboratories under optimal conditions, whereas seeds in the field are subject to a complicated soil matrix where they experience a variety of different stresses (Finch-Savage and Bassel 2015). Domestication and breeding have provided incremental improvements in the ability of crops to germinate and emerge under sub-optimal conditions, but here we discuss ways in which agronomically directed research could be applied to transform seed performance when surface soil is dry.

Soil water potential is a major factor in determining seed germination and plant establishment. Many species can germinate at soil water potentials well below those that maximise plant growth (Wuest and Lutcher 2013). Distinguishing between adequate and marginal water to enable germination can be difficult for growers – there are no well-defined criteria for determining if a soil contains a high enough water content to germinate different crop species. At water potentials above -1.1MPa, germination rates are rapid (Wuest and Lutcher 2013). Water potentials below this slow the speed of germination, and below -1.6MPa, germination ceases. Pawloski and Shaykewich (1972) showed that these effects were similar between soils, even when soils differ in hydraulic conductivity.

Crop establishment could be enhanced by the ability of seeds to germinate at lower water potentials. This could be achieved by genetic or other means. Singh et al. (2013) found differences between wheat cultivars in the ability to germinate at low water potentials. Genetic variation for rates of seed water uptake (which initiates germination and is the first stage in the malting process) exists in barley, and it has been suggested that this could be exploited by breeders for the benefit of the malting and brewing industries (Cu et al. 2016). The same principles and expertise could be applied to field germination at low water potential. An obvious trade-off that may arise with the genetic ability to germinate at low water potentials is susceptibility to pre-harvest sprouting (Rodríguez et al. 2015). Expertise from plant physiologists concerned with the regulation of dormancy would be essential to harness this opportunity.

Beyond genetic means, strategies for manipulating germination processes used in horticulture crops and rice could be evaluated. Seed priming techniques limit the availability of water to the seed so that imbibition and seed metabolism commences, but germination is not completed (Halmer 2004). Seed priming has potential to reduce the lag time between imbibition and emergence, and to synchronise seedling emergence. It can improve emergence of wheat under low temperatures (Farooq et al. 2008), but not necessarily under low water potentials (Giri and Schillinger 2003). The inclusion of plant growth regulators, hormones or micronutrients during priming can also improve germination and emergence (Jisha et al. 2013; Ali et al. 2018). It is clear from the literature there are many potential solutions that could improve seed germination and establishment at low water potentials. Extensive field appraisal of these techniques is required.

Inadequate moisture at the ideal sowing depth has led to growers sowing deeper to seek moist soil and to make use of residual moisture stored from summer rains or the previous growing season. Their ability to do this is currently restricted by the availability of sowing equipment capable of placing seeds into moist soil at depth, and the ability of plants to emerge from depth. Coleoptile length is an important trait determining the success of emergence from depth, but there are also other genetic factors involved (Mohan et al. 2013). Modern Australian semi-dwarf wheat and barley cultivars show poor emergence when sown deep (greater than 8cm) due to short coleoptiles (Rebetzke et al. 2007). Warmer soils in the future may further exacerbate poor establishment and especially with deep sowing.

Pre-experimental modelling indicates substantial benefits for crop yield in southern Australia if machinery and genotypes could be developed that allowed placement and emergence of seed at depth (Kirkegaard and Hunt 2010; Flohr et al. 2018a). Establishment of crops in this way is routine in the drylands of the Pacific North West USA, where annual rainfall in some regions is as low as 160mm. Seeds of winter wheat and other crops are sown deep using deep furrow drills into moisture remaining from 13-month fallow periods and can emerge with 10cm to 15cm of soil covering them (Schillinger and Papendick 2008). Rebetzke et al. (2016) have argued the case for Australian breeders to use novel dwarfing genes that do not suppress coleoptile length. Larger seed size is also known to improve deep-sown crop establishment. Large-seeded canola improved the timeliness of establishment and subsequent grain yield when rainfall for crop establishment was marginal but there was moisture available deeper in the seedbed (Brill et al. 2016).

Frost, drought and heat

While optimisation of flowering times allows the combined stresses of drought, frost and heat to be minimised, these abiotic stresses still take a large toll on crops every year, and will continue to do so even if establishment in the absence of autumn rain could be achieved (see preceding discussion within this paper). Most avenues minimising the risks of frost, drought and heat have been explored, the only remaining means to increase yields in the face of these cardinal abiotic stresses is through crop tolerance. It is our opinion that this will most likely be achieved via genetic solutions, but these must be considered in an appropriate G x E x M context.

Frost, drought and heat risks are inextricably linked. Frost risk declines as flowering is deayed later into the spring, while the risk of drought and heat increases. This means that tolerances to all three stresses are not necessary to improve yields, and if tolerance can be found to either frost on the one hand, or drought and heat on the other, then the optimal flowering period will shift accordingly to reduce the likelihood of occurrence of the opposing stress. That is, if we can minimise frost stress then we can reduce the effects of drought and heat stress by flowering earlier, and vice versa. The value of this approach has been demonstrated by economic analyses of potential frost tolerance, where the benefit of shifting flowering time earlier to avoid drought and heat has also been quantified (An-Vo et al. 2018). Therefore, the important question is which of these stresses will be cheapest and easiest to solve?

Drought and heat are perhaps easier targets compared with frost in that they are reasonably easy to screen for within a breeding program, and some genetic regions associated with combined drought and heat tolerance have been identified (Tricker et al. 2018). Conversely, frost is virtually impossible to recreate under controlled conditions and tolerance is extremely difficult to identify. Heat and drought often interact. Heat tolerance in the absence of drought is associated with stomatal opening and rapid water-use that depresses canopy temperatures relative to the atmosphere (Reynolds et al. 1994). For heat tolerance to be useful in the Australian context, it must be effective under limited water supply (Hunt et al. 2018; Tricker et al. 2018).

While there may be some promise in selecting morphological traits known to confer both heat and drought tolerance, the greatest and most cost-effective progress may be made by breeders selecting for high yield at late flowering times where crops would be routinely exposed to concurrent drought and heat stress. However, this is where the wider crop physiology and management context becomes important. It would be crucial that late flowering be achieved with slow developing cultivars sown early and thus exploit a full growing season rather than by late sowing of faster developing cultivars where yield potential would be limited by shallow rooting depth and low biomass accumulation (Kirkegaard et al. 2015; Lilley and Kirkegaard 2016).

Conclusion

Yield increases are necessary to keep Australian growers competitive in international markets and to feed a growing population without increasing the area of land devoted to farming. Yield increases can be achieved by closing yield gaps, or increasing water limited potential yield. Climate change has reduced water limited potential yield and the industry needs to increase its efforts if real yield gains are to be realised. Historically this has happened when new and old practices and technologies synergise in improved farming systems. We argue that research should focus on developing new systems to overcome current constraints to production and we identify three opportunities for future yield gains - minimising N limitations, establishment of crops in dry or marginal soil moisture, and combined drought and heat tolerance. To solve these problems will require multi-disciplinary teams working closely with growers and advisers in appropriate farming systems context.

Acknowledgements

The N bank experiment described in Figure 2 is funded by La Trobe University Research Focus Area 'Securing Food, Water and the Environment' and conducted in collaboration with BCG and CSIRO.

Useful resources

This GRDC update paper is based on the following book chapter:

Hunt, JR, Kirkegaard, JA, Celestina, C, Porker, K (2019) Transformational Agronomy: restoring the role of agronomy in modern agricultural research. In 'Australian Agriculture in 2020: From Conservation to Automation.' (Eds J Pratley, JA Kirkegaard.) pp. 373-388. (Agronomy Australia and Charles Sturt University: Wagga Wagga). http://www.agronomyaustraliaproceedings.org/index.php/special-publications

References

Ababaei, B, Chenu, K (2020) Heat shocks increasingly impede grain filling but have little effect on grain setting across the Australian wheatbelt. *Agricultural and Forest Meteorology* **284**, 107889.

Ali, N, Farooq, M, Hassan, MA, Arshad, MS, Saleem, MK, Faran, M (2018) Micronutrient seed priming improves stand establishment, grain yield and biofortification of bread wheat. *Crop and Pasture Science* **69**, 479-487.

An-Vo, D-A, Mushtaq, S, Zheng, B, Christopher, JT, Chapman, SC, Chenu, K (2018) Direct and Indirect Costs of Frost in the Australian Wheatbelt. *Ecological Economics* **150**, 122-136.

Anderson, WK, Heinrich, A, Abbotts, R (1996) Long-season wheats extend sowing opportunities in the central wheat belt of Western Australia. *Australian Journal of Experimental Agriculture* **36**, 203-208.

Angus, JF, Grace, PR (2017) Nitrogen balance in Australia and nitrogen use efficiency on Australian farms. *Soil Research* **55**, 435-450.

Asseng, S, McIntosh, PC, Wang, G, Khimashia, N (2012) Optimal N fertiliser management based on a seasonal forecast. *European Journal of Agronomy* **38**, 66-73.

Brill, RD, Jenkins, ML, Gardner, MJ, Lilley, JM, Orchard, BA (2016) Optimising canola establishment and yield in south-eastern Australia with hybrids and large seed. *Crop & Pasture Science* **67**, 409-418.

Cai, W, Cowan, T, Thatcher, M (2012) Rainfall reductions over Southern Hemisphere semi-arid regions: the role of subtropical dry zone expansion. *Scientific Reports* **2**,

Cu, S, Collins, HM, Betts, NS, March, TJ, Janusz, A, Stewart, DC, Skadhauge, B, Eglinton, J, Kyriacou, B, Little, A, Burton, RA, Fincher, GB (2016) Water uptake in barley grain: Physiology; genetics and industrial applications. *Plant Science* **242**, 260-269.

Dreccer, MF, Fainges, J, Whish, J, Ogbonnaya, FC, Sadras, VO (2018) Comparison of sensitive stages of wheat, barley, canola, chickpea and field pea to temperature and water stress across Australia. *Agricultural and Forest Meteorology* **248**, 275-294.

Farooq, M, Basra, SMA, Rehman, H, Saleem, BA (2008) Seed Priming Enhances the Performance of Late Sown Wheat (*Triticum aestivum* L.) by Improving Chilling Tolerance. **194**, 55-60.

Finch-Savage, WE, Bassel, GW (2015) Seed vigour and crop establishment: extending performance beyond adaptation. *Journal of Experimental Botany* **67**, 567-591.

Fischer, RA (2015) Definitions and determination of crop yield, yield gaps, and of rates of change. *Field Crops Research* **182**, 9-18.

Fischer, RA, Byerlee, D, Edmeades, GO (2014) 'Crop yields and global food security: will yield increase continue to feed the world? ACIAR Monograph No. 158.' (Australian Centre for International Agricultural Research: Canberra ACT)

Fischer, RA, Connor, DJ (2018) Issues for cropping and agricultural science in the next 20 years. *Field Crops Research* **222**, 121-142.

Fletcher, A, Lawes, R, Weeks, C (2016) Crop area increases drive earlier and dry sowing in Western Australia: implications for farming systems. *Crop and Pasture Science* **67**, 1268-1280.

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR (2017) Water and temperature stress define the optimal flowering period for wheat in south-eastern Australia. *Field Crops Research* **209**, 108-119.

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR, Lilley, JM (2018a) Genotype × management strategies to stabilise the flowering time of wheat in the south-eastern Australian wheatbelt. *Crop and Pasture Science* **69**, 547-560.

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR, Swan, A, Rheinheimer, B (2018b) Genetic gains in NSW wheat cultivars from 1901 to 2014 as revealed from synchronous flowering during the optimum period. *European Journal of Agronomy* **98**, 1-13.

Flohr, BM, Hunt, JR, Kirkegaard, JA, Evans, JR, Trevaskis, B, Zwart, A, Swan, A, Fletcher, AL, Rheinheimer, B (2018c) Fast winter wheat phenology can stabilise flowering date and maximise grain yield in semi-arid Mediterranean and temperate environments. *Field Crops Research* **223**, 12-25.

Giri, GS, Schillinger, WF (2003) Seed Priming Winter Wheat for Germination, Emergence, and Yield. **43**, 2135-2141.

Halmer, P (2004) Methods to improve seed performance in the field. In 'Seed Physiology: Applications to Agriculture.' (Eds RL Benech-Arnold, RA Sánchez.) (Food Products Press: Binghamton, NY)

Hochman, Z, Gobbett, DL, Horan, H (2017) Climate trends account for stalled wheat yields in Australia since 1990. *Global Change Biology* **23**, 2071–2081.

Hochman, Z, Horan, H (2018) Causes of wheat yield gaps and opportunities to advance the water-limited yield frontier in Australia. *Field Crops Research* **228**, 20-30.

Hochman, Z, van Rees, H, Carberry, PS, Hunt, JR, McCown, RL, Gartmann, A, Holzworth, D, van Rees, S, Dalgliesh, NP, Long, W, Peake, AS, Poulton, PL, McClelland, T (2009) Re-inventing model-based decision support with Australian dryland growers. 4. Yield Prophet® helps growers monitor and manage crops in a variable climate. *Crop and Pasture Science* **60**, 1057-1070.

Hunt, JR, Browne, C, McBeath, T, Verburg, K, Craig, S, Whitbread, AM (2013) Summer fallow weed control and residue management impacts on winter crop yield through soil water and N accumulation in a winter-dominant, low rainfall region of southern Australia. *Crop and Pasture Science* **64**, 922-934.

Hunt, JR, Hayman, PT, Richards, RA, Passioura, JB (2018) Opportunities to reduce heat damage in rain-fed wheat crops based on plant breeding and agronomic management. *Field Crops Research* **224**, 126-138.

Hunt, JR, Kirkegaard, JA, Celestina, C, Porker, K (2019a) Transformational Agronomy: restoring the role of agronomy in modern agricultural research. In 'Australian Agriculture in 2020: From Conservation to Automation.' (Eds J Pratley, JA Kirkegaard.) pp. 373-388. (Agronomy Australia and Charles Sturt University: Wagga Wagga)

Hunt, JR, Lilley, JM, Trevaskis, B, Flohr, BM, Peake, A, Fletcher, A, Zwart, AB, Gobbett, D, Kirkegaard, JA (2019b) Early sowing systems can boost Australian wheat yields despite recent climate change. *Nature Climate Change* **9**, 244-247.

Jisha, KC, Vijayakumari, K, Puthur, JTJAPP (2013) Seed priming for abiotic stress tolerance: an overview. **35**, 1381-1396.

Kirkegaard, JA (2019) Incremental transformation: success from farming systems synergy. *Outlook on Agriculture* **48**, 105-112.

Kirkegaard, JA, Hunt, JR (2010) Increasing productivity by matching farming system management and genotype in water-limited environments. *Journal of Experimental Botany* **61**, 4129-4143.

Kirkegaard, JA, Lilley, JM, Hunt, JR, Sprague, SJ, Ytting, NK, Rasmussen, IS, Graham, JM (2015) Effect of defoliation by grazing or shoot removal on the root growth of field-grown wheat (*Triticum aestivum* L.). *Crop & Pasture Science* **66**, 249-259.

Kitonyo, OM, Sadras, VO, Zhou, Y, Denton, MD (2017) Evaluation of historic Australian wheat varieties reveals increased grain yield and changes in senescence patterns but limited adaptation to tillage systems. *Field Crops Research* **206**, 65-73.

Lilley, JM, Flohr, BM, Whish, JPM, Farre, I, Kirkegaard, JA (2019) Defining optimal sowing and flowering periods for canola in Australia. *Field Crops Research* **235**, 118-128.

Lilley, JM, Kirkegaard, JA (2016) Farming system context drives the value of deep wheat roots in semi-arid environments. *Journal of Experimental Botany*

Liu, K, Harrison, MT, Hunt, J, Angessa, TT, Meinke, H, Li, C, Tian, X, Zhou, M (2020) Identifying optimal sowing and flowering periods for barley in Australia: a modelling approach. *Agricultural and Forest Meteorology* **282-283**, 107871.

Llewellyn, RS, D'Emden, FH, Kuehne, G (2012) Extensive use of no-tillage in grain growing regions of Australia. *Field Crops Research* **132**, 204-212.

Mohan, A, Schillinger, WF, Gill, KS (2013) Wheat Seedling Emergence from Deep Planting Depths and Its Relationship with Coleoptile Length. *PLoS ONE* **8**, e73314.

Pawloski, MC, Shaykewich, CF (1972) Germination of wheat as affected by soil water stress. *Canadian Journal of Plant Science* **52**, 619-623.

Pook, M, Lisson, S, Risbey, J, Ummenhofer, CC, McIntosh, P, Rebbeck, M (2009) The autumn break for cropping in southeast Australia: trends, synoptic influences and impacts on wheat yield. *International Journal of Climatology* **29**, 2012-2026.

Pugsley, AT (1983) The impact of plant physiology on Australian wheat breeding. *Euphytica* **32**, 743-748.

Rebetzke, GJ, Richards, RA, Fettell, NA, Long, M, Condon, AG, Forrester, RI, Botwright, TL (2007) Genotypic increases in coleoptile length improves stand establishment, vigour and grain yield of deep-sown wheat. *Field Crops Research* **100**, 10-23.

Rebetzke, GJ, Zheng, B, Chapman, SC (2016) Do wheat breeders have suitable genetic variation to overcome short coleoptiles and poor establishment in the warmer soils of future climates? *Functional Plant Biology* **43**, 961-972.

Reynolds, M, Balota, M, Delgado, M, Amani, I, Fischer, R (1994) Physiological and morphological traits associated with spring wheat yield under hot, irrigated conditions. *Functional Plant Biology* **21**, 717-730.

Rodríguez, MV, Barrero, JM, Corbineau, F, Gubler, F, Benech-Arnold, RL (2015) Dormancy in cereals (not too much, not so little): about the mechanisms behind this trait. *Seed Science Research* **25**, 99-119.

Sadras, VO, Lawson, C (2011) Genetic gain in yield and associated changes in phenotype, trait plasticity and competitive ability of South Australian wheat varieties released between 1958 and 2007. *Crop & Pasture Science* **62**, 533-549.

Schillinger, WF, Papendick, RI (2008) Then and Now: 125 Years of Dryland Wheat Farming in the Inland Pacific Northwest. **100**, S-166-S-182.

Schwenke, GD, Manning, W, Haigh, BM (2014) Ammonia volatilisation from nitrogen fertilisers surface-applied to bare fallows, wheat crops and perennial-grass-based pastures on Vertosols. *Soil Research* **52**, 805-821.

Siddique, KHM, Tennant, D, Perry, MW, Belford, RK (1990) Water-use and water-use efficiency of old and modern wheat cultivars in a Mediterranean-type environment. *Australian Journal of Agricultural Research* **41**, 431-447.

Singh, P, Ibrahim, HM, Flury, M, Schillinger, WF, Knappenberger, T (2013) Critical water potentials for germination of wheat cultivars in the dryland Northwest USA. *Seed Science Research* **23**, 189-198.

Smith, CJ, Hunt, JR, Wang, E, Macdonald, BCT, Xing, H, Denmead, OT, Zeglin, S, Zhao, Z (2019) Using fertiliser to maintain soil inorganic nitrogen can increase dryland wheat yield with little environmental cost. *Agriculture, Ecosystems & Environment* **286**, 106644.

Stephens, DJ, Lyons, TJ (1998) Variability and trends in sowing dates across the Australian wheatbelt. *Australian Journal of Agricultural Research* **49**, 1111-1118.

Tricker, PJ, ElHabti, A, Schmidt, J, Fleury, D (2018) The physiological and genetic basis of combined drought and heat tolerance in wheat. *Journal of Experimental Botany* **69**, 3195-3210.

Turner, DA, Edis, RE, Chen, D, Freney, JR, Denmead, OT (2012) Ammonia volatilization from nitrogen fertilizers applied to cereals in two cropping areas of southern Australia. *Nutrient Cycling in Agroecosystems* **93**, 113-126.

van Herwaarden, AF, Farquhar, GD, Angus, JF, Richards, RA, Howe, GN (1998) 'Haying-off', the negative grain yield response of dryland wheat to nitrogen fertiliser. I. Biomass, grain yield, and water use. *Australian Journal of Agricultural Research* **49**, 1067-1082.

van Ittersum, MK, Cassman, KG, Grassini, P, Wolf, J, Tittonell, P, Hochman, Z (2013) Yield gap analysis with local to global relevance—A review. *Field Crops Research* **143**, 4-17.

van Rees, H, McClelland, T, Hochman, Z, Carberry, P, Hunt, J, Huth, N, Holzworth, D (2014) Leading growers in South East Australia have closed the exploitable wheat yield gap: Prospects for further improvement. *Field Crops Research* **164**, 1-11.

Wuest, SB, Lutcher, LK (2013) Soil Water Potential Requirement for Germination of Winter Wheat. *Soil Science Society of America Journal* **77**, 279-283.

Contact details

Assoc. Prof. James Hunt
Department of Animal, Plant and Soil Sciences
La Trobe University, Bundoora VIC 3086
0428 636 391
j.hunt@latrobe.edu.au
@agronomeiste

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Notes

Cereal production in the United Kingdom (UK) with regulation, resistance and a changing climate

Keith Norman.

Independent Agritech Consultant; Keith Norman Consultancy Ltd..

Keywords

- regulation, resistance, yield plateau, yield gap, remote sensing, soil health, soil nutrition, fungicides, immune enhancers, semiochemicals, robotics, big data.

Take home messages

- Reliance on conventional pesticides will diminish from the effects of regulation and resistance.
- Plant breeding and genetics have a vital part to play in the sustainability of crop production.
- There are many emerging applied technologies that will underpin the sustainability of future crop production.

Regulation

The European Union (EU) has one of the most heavily regulated agricultural industries globally. The United Kingdom (UK)'s agrochemical (Agchem) market is affected by all of the following regulations:

- Regulation 1907/2006 concerning the Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH).
- Regulation 1107/2009 on the Placing on the Market of Plant Protection Products (PPPR). Aims to draft 'specific scientific criteria for the determination of endocrine disrupting properties'. Deadline was originally 2013, the criteria were adopted only in 2018.
- Regulation 528/2012 on Biocidal Products (BPR).
- Regulation 2018/605 Endocrine Disruption.
- Regulation 2000/60 Water Framework Directive.

In 1993, the EU launched a review of approximately all of the 1000 active substances in the EU.

Each substance had to be evaluated with respect to human health (consumers, farmers, local residents and passers-by) the environment, groundwater, and non-target organisms, such as birds, mammals, earthworms and bees. This review program was finalised in March 2009. Some manufacturers decided not to submit dossiers. Some products were no longer profitable, or the active substances would not pass the stricter safety testing requirements. Only 26% of the actives survived the review.

Table 1. Active ingredients that are no longer available.

Chlorothalonil	Carbendazim	Diquat	CIPC	Fenoxaprop
Neonicotinoids	Methiocarb	Flupyrsulfuron	Flurtamone	Flusilazole
Fenpropimorph	Fluazifop	Iprodione	Isoproturon	Linuron
Glufosinate	Ioxynil	Paraquat	Permethrin	Picoxystrobin
Mecoprop	Omethoate	Simazine	Tepraloxydim	Terbutryn
Quinoxyfen	Quizalofop	Tralkoxydim	Tridemorph	Vinclozolin
Thiamefoxam	Thiram	Desmedipham	Dimethanamid	Gamma HCH

Active Ingredients that are considered high risk of being removed in the next two to three years:

Fungicides	Epoxiconazole, Tebuconazole, Cyproconazole, Metconazole, Mancozeb.
Herbicides	2,4-D, Bifenox, Carbetamide, Chlortoluron, Clopyralid, Fluroxypyr, Glyphosate (Austria, France and Germany have already announced a ban), Metazachlor, MCPA, Pendamethalin Propyzamide.
Insecticides	Cypermethrin, Deltamethrin, Esfenvalerate, Thiacloprid, Metaldehyde.

What have been the effects of this more stringent system?

Tougher regulation has led to manufacturers submitting less actives for approval.

During the 1990s over 120 new actives were submitted for approval, but this has reduced to less than 40 in the last decade.

Because of the more stringent criteria the costs of bringing a new active to market has increased from $184m in 2000 to $286m (current). Maximum Residue Levels, Ecotox, Environmental Chemistry and Toxicology are some of the significant costs of registering a new product.

There is a much greater threat of resistance development due to fewer modes of action being available for fungicide, herbicide and insecticide options, and therefore, increased selection pressure on what remains.

Active ingredients (AIs) with a single site of action are more favoured in the new system and are more vulnerable to forming resistance than the broad-spectrum multiple site of action AIs.

The manufacturer pipeline of new actives does not seem likely to deliver a wide range of replacement AIs.

Biological controls are in their infancy and are not ready for scale up. They are also very poorly understood and early indications of their performance reliability is hugely variable and weather dependent.

What are UK growers doing to mitigate the dwindling stock of effective plant protection products?

Strategies used by UK growers to mitigate dwindling stock of effective plant protection products:

- Choosing varieties with greater disease resistance.
- Seeding later which reduces disease potential.
- Being more selective of where they grow crops on the farm. They don't grow crops on areas with heavy weed burdens, or inherently less productive areas due to topography, soil type, drainage, etc. Environmental payments are going to take the place of subsidies, the details are yet to be announced.
- Growing more barley and less wheat. It's cheaper to grow and yields are sometimes as good as wheat.
- More spring cropping; which enables an increase in use of non-selective grass weed herbicides and spreads autumn workload.
- Spring beans, spring barley and maize for anaerobic digestors have had the most significant increases.
- The Environmental Land Management Scheme will replace subsidies and will generate income on less favoured areas for crop production.
- Reduce the area of combinable crops and rent land out for potato, sugar beet and vegetables on short-term agreements.
- Greater use of high-technology monitoring tools. For example, DNA fungal spore detectors, insect suction traps, remote sensing using unmanned aerial vehicles (UAVs), satellites, etc.
- Decision support modelling is being developed to use the information from the new Internet of Things together with location, weather, cultivars and the growth period.
- Investigations into the many biological products coming onto market is beginning to take place. In the last three years, registration applications for biologicals have been greater than conventional chemistry.

Resistance in the UK

Resistance is becoming more widespread and at a faster rate of development than ever before. The following are examples of major resistances UK growers are having to manage.

Fungicides	Herbicide	Insecticide
Septoria	Blackgrass	Grain aphid
Mildew	Ryegrass	Peach Potato Aphid
Light Leaf Spot	Poppy	Cabbage Stem Flea Beetle
Potato Blight	Chickweed	Pollen beetle
	Mayweed	Pea and Bean Weevil

Repeated use of a smaller number of active ingredients adds more selection pressure to the remaining options.

Over the last 20 years, we have seen the efficacy of triazoles in a protectant and curative capacity drop significantly from > 90% from when they were first introduced to approximately 30% today.

In more detailed studies, the EC_{50} (effective concentration) of the two key triazoles; epoxiconazole and prothioconazole have steadily increased from 0.01ppm to 5ppm for epoxiconazole, and from 0.001ppm to 1.5ppm for prothioconazole.

It is common to find the coexistence of between five to eight resistant populations in the one field. Not only are there mutations to the CYP51 protein that the triazoles bind to, but there are also two other types of resistance becoming commonplace; an over-expression gene whereby the mutated protein amplifies to greater levels than normal. There is also a mutation that affects the Efflux pump mechanism, whereby the Septoria cells actively pump out the fungicide from within to minimise the effect of the fungicide on them.

Likewise, we are seeing a marked reduction in the efficacy of succinate dehygrogenase inhibitors (SDHIs). From 2015 to 2019, their average performance had dropped from >90% to approximately 60%

The increase of resistance to pyrethroids is also concerning, especially now that neonicotinoid seed treatments are no longer permitted. It is estimated that between 30-50% of grain aphids (English Grain Aphid, *Sitobion avenae*) now carry the KdR gene. This is also reflected in the decrease of the area sown to oilseed rape due to the lack of control of the Cabbage Stem Flea beetle (*Psylliodes chrysocephalus*). Oilseed rape (OSR) grown in the UK has dropped from 758,000ha in 2012 to an estimated 483,00ha for harvest 2020.

Autumn 2019 saw the arrival of the first barley yellow dwarf virus (BYDV) resistant wheat from RAGT, a variety called Wolverine. Wolverine's resistance originates from a goat grass, *Thinopyrum intermedium*, a distant wheat relative. A genetic segment from Thinopyrum containing the resistance gene Bdv2 has been translocated onto a wheat chromosome via an Australian research line known as TC14.

Myzus persicae is totally resistant to pyrethroids causing problems for virus control in potatoes and sugar beet There are two BYDV resistant barley varieties and six TuMV resistant OSR varieties on the market presently.

Grass weed herbicide resistance, principally black grass and ryegrass, is a significant problem on approximately 1M hectares of wheat (50% of the UK hectarage) Both target site and enhanced metabolic resistance coexist within fields. We are beginning to see resistance building with some of the residual chemistry too; flufenacet and pendimethalin.

Of greatest concern is the observation of some blackgrass populations now becoming insensitive to doses of 540g/ha of glyphosate which would normally have been effective.

Finally, there are four broadleaved weed species that are now resistant to sulfonylurea herbicides, they are poppy (*Papaver somniferum*), chickweed (*Stellaria media*), mayweed (*Matricaria*) and sowthistle (*Sonchus asper*).

The Yield Plateau

The phenomenon of the 'yield plateau' extends further than just the UK. A similar situation exists in other countries of Western Europe. From 1980 to 1996, UK wheat yields improved rapidly; by an average of 0.10t/ha per year. Since then, yields have stagnated, increasing by only 0.05t/ha per year.

No single agronomic factor has had a clear dominant influence on trends in UK wheat yields over the last 30 years. A proportion of the lost yield improvement remains unexplained, with aspects of climate change being amongst the likely causes. Plant breeding has continued to deliver genetic improvement.

Several theories have been put forward as to why yield has plateaued such as soil health, soil management and cultivations, compaction from heavier machinery, suboptimal nitrogen (N) and sulphur use, pesticide resistance, sowing dates and seed rates.

The Yield Gap

There is a considerable 'yield gap' between average UK wheat yields, currently approximately 8.5t/ha and the top achieving growers. In 2019, the top Yield Enhancement Network (YEN) of growers reported an actual yield of between 14t/ha to 16t/ha, with the world record still set at 16.5t/ha.

According to YEN, 75% of yield variation is influenced by the farm's physical characteristics, crop husbandry, the agronomist and the farmer. High biomass and ear numbers are essential for high yields. The foundation period; seeding to GS31, is a very important period and crop development within this period is very heavily influenced by soil management, nutrition and good root development.

Moisture retentive soils are key to ensuring grain fill is optimum. There is a positive association with organic amendments, particularly slurry and digestate. Site, weather and husbandry factors have a bigger influence than variety choice, and therefore, varieties should be chosen for quality traits, end markets, disease resistance and standing ability rather than just yield.

There is a positive association with soil pH and with straw incorporation. The association with N fertiliser rate is very strong.

Early indication is that phosphate (P) grain content is also correlated to yield, the critical value for grain P = 3200mg/kg.

There is a negative association with liquid N probably due to the scorching of the crop if it is applied in the wrong conditions. Because high biomass and ear numbers are important, plant growth regulator (PGR)-use has a strong positive association with yield. High straw N% and soluble stem carbohydrate reserves were considered very important to maintain photosynthesis during grain filling.

New technologies being introduced

There are several new technologies being developed which will hopefully increase production potential.

Plant breeding and genetics

The first BYDV resistant wheat and barley in the UK has previously been discussed within this paper. However, there are also exciting developments using a Synthetic Hexaploid breeding approach whereby one of the three wheat genomes, the D genome, is being replaced from other sources of material resulting in greater yields, and greater resistance to biotic and abiotic stress.

Work at the John Innes Centre is also looking at producing grains with increased length and width, thereby increasing the 'sink' for higher yields. Other attributes are also being researched, for example; longer spikelets that produce approximately 20% more grains, a branched ear producing 50% more grains, etc.

Advances in genetic marker-assisted speed breeding, whereby up to six generations can be achieved per year through controlled environment and Light Emitting Diode (LED) technology are enabling more rapid translation of genetic discovery into elite lines.

Remote sensing

There are many new capabilities being developed to assist the farmer and agronomist to manage crops more effectively, many of which are satellite based.

Monitoring of crop health through normalised difference vegetation index (NDVI) measurements, biomass measurements, Green Area Index, crop growth rate, plant stress are all operational and enable farmers/agronomists to target their time more effectively by targeting the inspection of problem areas of paddocks rather than general field walking.

Hyperspectral, pre-symptomatic disease signatures are currently being developed in Controlled Environment conditions by Hummingbird Technologies.

Ground Penetration Radar is now available from satellites and has the capability of penetrating soils up to 1m. This technology has the capability of detecting compaction in subsoils, as well as soil moisture for irrigation scheduling purposes.

Another form of remote sensing; Synthetic Aperture Radar, is an active wavelength which has the potential to penetrate cloud and can also deliver information in the dark.

Field based spore sensors that can be primed to detect the DNA of multiple diseases from the surrounding air are also being developed and would be another key feature in the early detection and intervention of disease ingression. Portable LAMP assay kits are now becoming available whereby growers can take leaf samples and look for the presence of pathogen DNA on recently emerged leaves.

Another approach is a 3D printed spore trap being developed by the University of Manchester and Sony. A mimic leaf is embedded with sensors that look for the presence of disease enzymes that are used to penetrate the vascular system of the plant and wreak havoc, or pressure sensors to detect the appressorium (pegs) that some diseases; such as rust, use to enter the leaf surface.

Soil health and nutrition

Volatile Organic Compounds (VOCs) are the basis of a new infield technology being developed by PES technologies. The small detector, about the size of a matchbox, is filled with soil and the VOCs that are detected give an indication of the key indicators of soil health.

Variable rate N capabilities are now commonplace with the more progressive farmers.

The age-old debate as to whether to put more or less N on the poorer parts of the crop rages on. A new product from Hummingbird technologies enables growers to test the option of inversing the approach to N at the click of a box. In practical terms, if extra N applied on the lower biomass areas of the crop hasn't produced a positive effect, then less will be applied on the second split, thereby optimising gross margins.

More knowledge is being developed regarding optimum nutritional thresholds during the key stages of crop development. Tissue and grain testing are becoming a more reliable method to test nutrient levels compared to soil testing.

Infield soil sensors are starting to make an appearance. The Terralytic soil probe has 26 sensors and measures soil moisture, salinity, and N, phosphorus (P) and potassium (K) at three different depths, as well as aeration, respiration, air temperature, light, and humidity

The Terramap, which is a small measuring device fitted to an all-terrain vehicle (ATV), measures four naturally emitted isotopes - Caesium-137 (Cs), Uranium-238 (U), Potassium-40 (K) and Thorium-232 (Th). There are approximately 800 reference points per hectare. In comparison, grid sampling map layers have only a single data point per hectare. Strategic soil samples are taken from each paddock and then the scan data and soil sample results are combined and processed to produce up to 21 high-definition soil property layers; P, K, magnesium (Mg), pH and % of clay, sand, silt, calcium, sodium, manganese, boron, copper, molybdenum, iron, zinc, sulphur, organic matter (OM), salinity (CEC) and plant available water are all delivered.

Fungicides, immune enhancers and semiochemicals

After a long time, two new fungicides have arrived on the UK market this season. The first is Revysol® (mefentrifluconazole), a new type of triazole, an isopropanol-Azole, which has been a top performer in AFD trials this year. The second is awaiting imminent approval, InatreqTM from Corteva which is based on a fermentation product of a soil borne Streptomyces bacteria. This has a very similar mode of action as the strobilurins; it acts on complex 3 of the mitochondria.

Plant immune enhancers have been introduced into the market, but their use in terms of timing, dose and frequency is still to be determined. They are based on both systemic acquired resistance and induced systemic resistance. They work by stimulating the salicylic and jasmonic acid pathways. If successful in their development, they could be an important part of a resistance management program

Semiochemical technologies are also currently being developed. An example is; jasmonic acid which naturally repels insects and tricks insects into believing the host is decaying and under attack, and therefore, the plant would not make a viable host.

Others disrupt the mating cycle of insects by confusing the male insect so that it is unable to find a female to mate with. This reduces pest populations.

Attractants can also be used to lure insects into traps containing insecticides. These can be used in conjunction with evolving 'smart trap' technologies whereby insect species are identified and counted, enabling more effective insect control management strategies.

Alternatives to herbicides

The future of glyphosate still hangs in the balance following the current approval period which ends in 2022. Various other techniques are being investigated, for example; the use of pelargonic acid, laser weeding and electronic weeding.

Hight voltage weeding, while very effective and quick in the resulting kill, still must overcome the practical difficulties of generating enough tractor mounted voltage to optimise width and speed of travel.

Laser weeding, whether by robots or boom mounted is more appropriate for wide-row horticulture crops rather than broadacre commodity crops.

Pelargonic acid as a standalone product is not as active on weeds as glyphosate but can considerably enhance the effect of low rates of glyphosate. It has a high application rate of 20-30L/ha which has implications for application and storage

Robotics

There is a lot of activity in this area, but most of the technologies are going to be more suited to horticulture/top fruit crops rather than broadacre commodity crops. Fruit sizing, colour detection and picking are all being developed as well as laser weeding.

The Small Robot Company is developing a partnership of robots – one detects, the other implements. They have a philosophy of 'per plant' establishment and management which they believe will replace conventional methods.

Big data

Finally, 'big data' is a direct consequence of the Internet of Things in agriculture. I don't think we have yet seen the full extent of the advantages of the use of 'big data'. A new UK government funded Agritech Centre, Agrimetrics is developing new services for farming that utilise 'big data'.

Data, at a global level, is on an exponential rate of use, and has increased from 30-40 zettabytes from 2019 to 2020 (1 Zb = 1 trillion gigabytes).

Omnia, a GIS service on offer from Hutchinsons can analyse multi- layers of crop information to give more insight into the output potential of a specific paddock. Yield data from combines, soil sampling, etc. can be compared across many seasons and variable rate applications adjusted accordingly.

Useful references

Regulation (EC) 1107/2009 on the Placing of Plant Protection Products on the Market,

http://www.europarl.europa.eu/RegData/etudes/STUD/2018/615668/EPRS_STU(2018)615668_EN.pdf

European Commission, Communication from the Commission to the Council and the European Parliament - Community strategy for endocrine disrupters - A range of substances suspected of interfering with the hormone systems of humans and wildlife, COM (1999)706 final, 1999. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex:51999DC0706

Registering a Pesticide: http://www.pesticides.gov.uk/guidance/industries/pesticides/topics/pesticide-approvals/pesticidesregistration/ ; registering-a-pesticide.htm

Pesticides Usage Survey: https://secure.fera.defra.gov.uk/pusstats/surveys/

Fungicide resistance action group https://ahdb.org.uk/frag

Insecticide resistance action group https://www.irac-online.org/

Weed resistance action group https://ahdb.org.uk/wrag

Yield Plateau – report commissioned by AHDB https://ahdb.org.uk/Tags/Yield%20Plateau

Yield enhancement network (YEN), connects agricultural organisations and farmers who are striving to improve crop yields: https://www.yen.adas.co.uk/

AHDB Fungicide Performance, independent information on the efficacy of fungicides against key diseases in wheat, barley and oilseed rape: https://ahdb.org.uk › fungicide-performance

Tissue derived optimum nutrient thresholds for wheat: https://www.lancrop.com/

Teralytic Wireless NPK soil probe and an analytics platform: https://teralytic.com/

Terramap – passive, gamma-ray detection technology providing high-definition mapping of all common nutrient properties: https://www.omniaprecision.co.uk/terramap/

Omnia Precision: https://www.omniaprecision.co.uk/

Small Robot Company: https://www.smallrobotcompany.com/meet-the-robots#weed-killing

Hummingbird Technologies, crop data analytics using satellites, fixed wing and drones: https://hummingbirdtech.com/

Electronic weeding: https://zasso.com/

Agrimetrics, provides data, tools and services to agrifood businesses: https://agrimetrics.co.uk/

Contact details

Keith Norman,
Independent Agritech Consultant,
keith@keithnorman.com
@KeithNorman_Ag

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Notes

TOP 10 TIPS

FOR REDUCING SPRAY DRIFT

01 **Choose all products in the tank mix carefully**, which includes the choice of active ingredient, the formulation type and the adjuvant used.

02 **Understand** how product uptake and translocation may impact on coverage requirements for the target. Read the label and technical literature for guidance on spray quality, buffer (no-spray) zones and wind speed requirements.

03 **Select the coarsest** spray quality that will provide an acceptable level of control. Be prepared to increase application volumes when coarser spray qualities are used, or when the delta T value approaches 10 to 12. Use water-sensitive paper and the Snapcard app to assess the impact of coarser spray qualities on coverage at the target.

04 **Always expect** that surface temperature inversions will form later in the day, as sunset approaches, and that they are likely to persist overnight and beyond sunrise on many occasions. If the spray operator cannot determine that an inversion is not present, spraying should NOT occur.

05 **Use weather forecasting** information to plan the application. BoM meteograms and forecasting websites can provide information on likely wind speed and direction for 5 to 7 days in advance of the intended day of spraying. Indications of the likely presence of a hazardous surface inversion include: variation between maximum and minimum daily temperatures are greater than 5°C, delta T values are below 2 and low overnight wind speeds (less than 11km/h).

06 **Only start spraying** after the sun has risen more than 20 degrees above the horizon and the wind speed has been above 4 to 5km/h for more than 20 to 30 minutes, with a clear direction that is away from adjacent sensitive areas.

07 **Higher booms increase drift**. Set the boom height to achieve double overlap of the spray pattern, with a 110-degree nozzle using a 50cm nozzle spacing (this is 50cm above the top of the stubble or crop canopy). Boom height and stability are critical. Use height control systems for wider booms or reduce the spraying speed to maintain boom height. An increase in boom height from 50 to 70cm above the target can increase drift fourfold.

08 **Avoid high spraying speeds**, particularly when ground cover is minimal. Spraying speeds more than 16 to 18km/h with trailing rigs and more than 20 to 22km/h with self-propelled sprayers greatly increase losses due to effects at the nozzle and the aerodynamics of the machine.

09 **Be prepared** to leave unsprayed buffers when the label requires, or when the wind direction is towards sensitive areas. Always refer to the spray drift restraints on the product label.

10 **Continually monitor** the conditions at the site of application. Where wind direction is a concern move operations to another paddock. Always stop spraying if the weather conditions become unfavourable.
Always record the date, start and finish times, wind direction and speed, temperature and relative humidity, product(s) and rate(s), nozzle details and spray system pressure for every tank load. Plus any additional record keeping requirements according to the label.

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Cereal disease update 2020

Grant Hollaway[1], Mark McLean[1], Hugh Wallwork[2], Art Diggle[3], Fran Lopez Ruiz[4] and Robert Park[5].

[1]Agriculture Victoria, Horsham; [2]South Australian Research and Development Institute (SARDI), Adelaide; [3]Department of Primary Industries and Regional Development (DPIRD), Perth; [4] Centre for Crop and Disease Management, Curtin University, Bentley, WA; [5]The University of Sydney.

GRDC project codes: DJP1907-001RTX, DAW1810-007RTX, DJP1907-004RTX, DJP1907-002RMX, DJP1905_002SAX, CUR00023, CUR1905-001SAX

Keywords

- stripe rust, net form of net blotch, NFNB, oat diseases, decision support app, fungicide resistance.

Take home messages

- The proactive use of different management options in combination (such as variety selection, paddock selection and appropriate fungicide use), provides proven sustainable and economic control for both root and foliar diseases.
- A new strain of stripe rust is important to durum wheat and some bread wheats with new ratings published in the 2020 Victorian Disease Guide.
- A new decision support tablet-based app will help in the management of stripe rust.
- Recent reports of fungicide resistance in cereal pathogens highlight the importance of avoiding fungicide use that increase the likelihood of resistance development.

Background

The good start to the 2019 season favoured early foliar disease development but did not continue as dry spring conditions mostly limited further disease progress. Despite this dry finish to the season, field experiments by Agriculture Victoria demonstrated yield losses of 8 to 18% due to net form of net blotch (NFNB) in the Wimmera and Mallee when highly susceptible cultivars were planted, infected stubble was present, and fungicides not applied. This highlights the importance of implementing disease management strategies to minimise yield losses.

Cereal disease management in 2020

Cereal diseases will require proactive management prior to and during the 2020 season. A disease management plan should consider the variety disease rating (consult a current disease guide) and inoculum loads within a paddock (stubble and soilborne diseases) and the district (consider any green bridge). A fungicide strategy should be developed for each crop, based on identified risks and being mindful of avoiding over-reliance on, or overuse of, fungicides. Diseases can be cost effectively controlled when a proactive management approach is used.

Wheat stripe rust

During 2019 there was a late outbreak of stripe rust in wheat crops, particularly in the variety LRPB Trojan⁽ᴾ⁾ due to the occurrence of a new pathotype. This late outbreak caused concern about the merits of fungicide applications late in the season. A new stripe rust app, StripeRust Wheat Management (StripeRustWM), will help with difficult decisions around in-crop fungicide control.

Rust pressure is expected to be relatively low during 2020 given the hot and dry conditions during December. These conditions have provided an effective control of the green bridge thus reducing rust carry over into the 2020 season. This reduced risk from rust can be factored into 2020 rust management plans.

A new stripe rust pathotype

During 2019, there were reports of stripe rust in the wheat varieties LRPB Trojan$^{\phi}$ and DS Bennett$^{\phi}$ at higher than expected levels. These reports were most likely related to a new stripe rust strain (pt. 198 E16 A+ J+ T+ 17+) that was first detected in 2018. It was isolated from Victoria and Tasmania later in 2018, and in 2019 from NSW (four isolates), Victoria (two isolates), and Queensland (one isolate). This pathotype is a simple mutational derivative of pt. 134 E16 A+ J+ T+ 17+, that is, from the 'Western Australian' family of stripe rust pathotypes, with added virulence for the differential Suwon 92/Omar. Given that the resistance of Suwon 92/ Omar has not been fully characterised, The University of Sydney is currently undertaking studies to fully understand the implications of this new pathotype.

Data collected from the field during 2019 by NSW DPI and AgVic, as part of the GRDC's National Variety Trials (NVT) disease rating project, indicated that this new pathotype has implications for several wheat varieties, such as DS Bennett$^{\phi}$ and LPB Trojan$^{\phi}$ and to a lesser extent Devil$^{\phi}$, Illabo$^{\phi}$, DS Darwin$^{\phi}$, Emu Rock$^{\phi}$ and Hatchet CL Plus$^{\phi}$. There were also implications for several durum varieties, such as DBA Spes$^{\phi}$, DBA Lillaroi$^{\phi}$, DBA Vittaroi$^{\phi}$ and EGA Bellaroi$^{\phi}$.

The ratings published in the 2020 Victorian cereal disease guide have been updated and consider this as well as the other pathotypes known to occur in Victoria. It is important to always consult a current disease guide due to changes such as these.

Decision support for stripe rust control: StripeRustWM

A new tablet-based app, StripeRustWM, has been developed to support in-crop decision making for the management of stripe rust of wheat. The app is based on the already successful BlacklegCM and SclerotiniaCM apps that are widely used in canola. StripeRustWM estimates potential losses using information including variety resistance

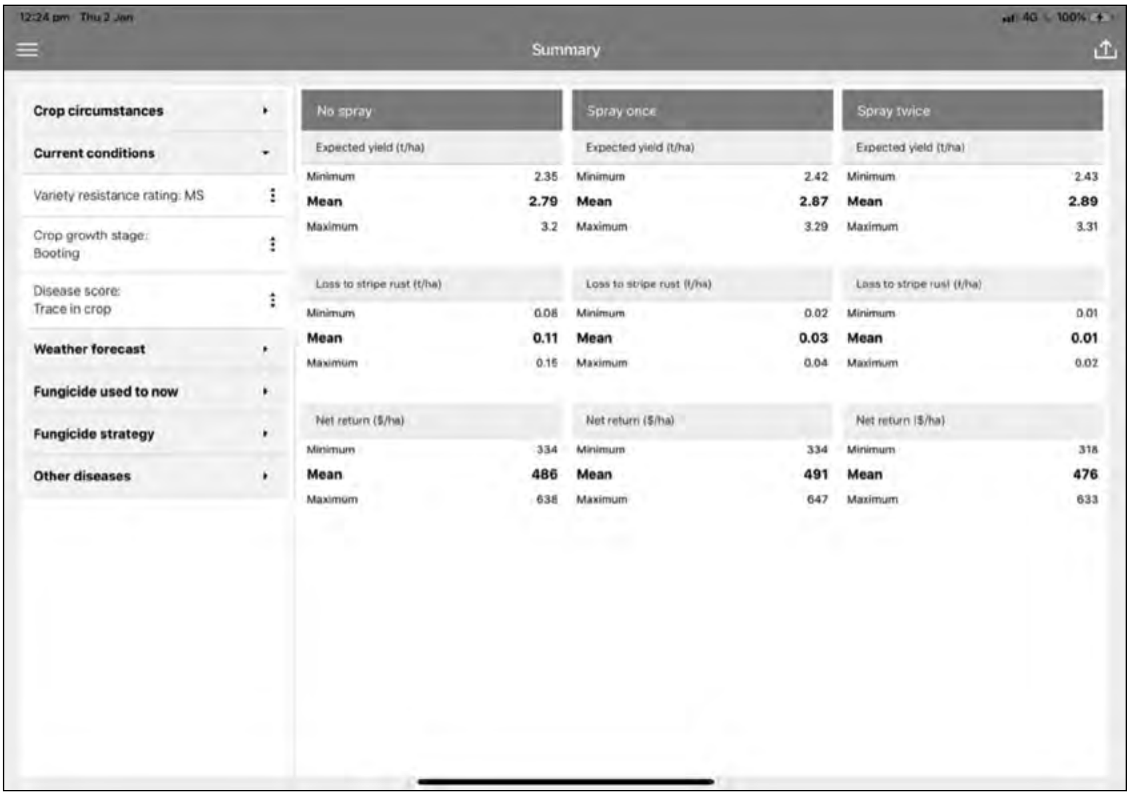

Figure 1. The summary view from StripeRust Wheat Management (StripeRustWM) comparing expected yield, loss to stripe rust and net return for the cases where fungicide is not applied, is applied once, or is applied twice.

rating, plant growth stage, fungicide history, presence of rust either within the crop or the district, climatic conditions, expected yield and economics. StripeRustWM was developed using data and information from the last 30 years' national pathology research projects. The app will be updated annually with the latest research findings so that new information can be utilised by industry as soon as available.

StripeRustWM is designed to be quick to use in the field, to guide profitable decisions about stripe rust management. It has a straight-forward user interface that asks for inputs that can be readily estimated by agronomists.

Figure 1 illustrates the StripeRustWM app interface, where a trace of stripe rust has been detected in a crop with a resistance rating of moderately susceptible (MS), at the booting growth stage. The output shows that a marginally higher net return would be expected if fungicide was applied to the crop once, compared with not spraying. The net return would probably be lower if the crop were sprayed twice.

An alternate presentation of the StripeRustWM app is shown in Figure 2, illustrating the range of possible outcomes, as a probability, from a single fungicide application. This reflects the variable nature of a biological system where a range of outcomes are possible. It shows the relative likelihood of positive and negative returns from the spray based on different environmental conditions and yield potentials.

StripeRustWM is available at no cost for iPads or Android tablets from the Apple App Store or Google Play — search for 'StripeRustWM'.

Net form of net blotch

Net form of net blotch (NFNB) is becoming a common foliar disease of barley in Victoria due to the adoption of susceptible varieties such as RGT Planet⦶ and moderately susceptible varieties such as Compass⦶. A survey of 80 barley crops across Victoria during 2019 found NFNB in 11% of paddocks. Severity was relatively low, ranging between 1 to 15% of leaf area infected, which was due to proactive fungicide strategies and/or dry spring conditions not favouring NFNB development. This level, however, serves as a warning for potential damage in conducive seasons.

During 2020, the risk of loss due to NFNB will be greatest where susceptible varieties are sown into barley stubble from either of the last two years. NFNB is seed and wind-borne, and therefore can establish in crops where there is no recent paddock history of barley. A new NFNB strain virulent on Spartacus CL⦶ has been found in SA

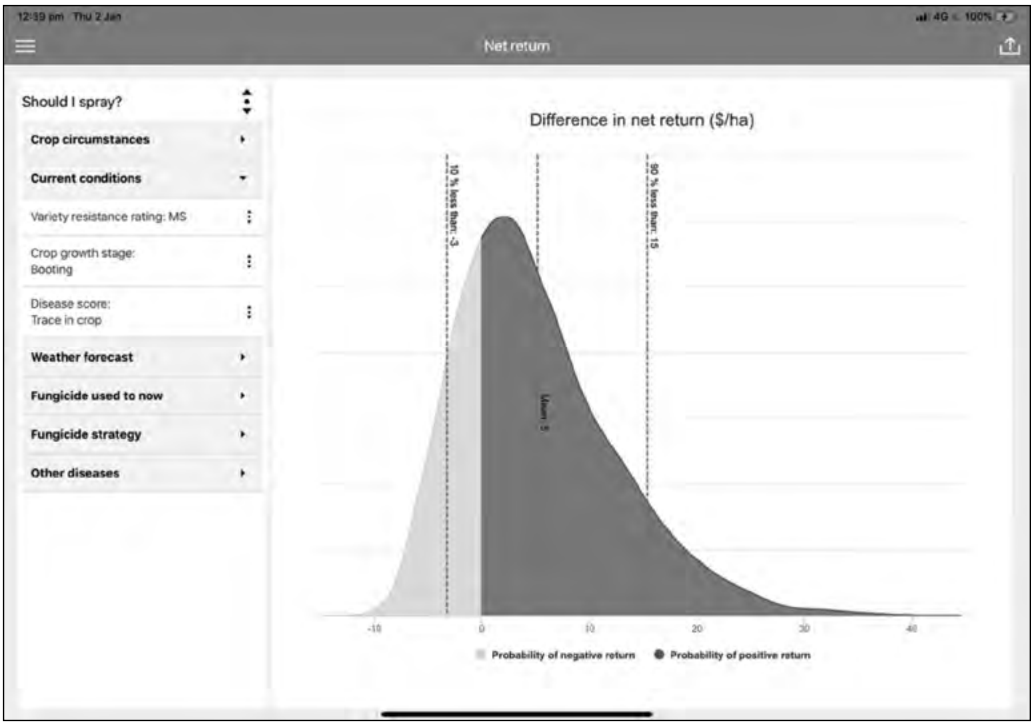

Figure 2. The net return view from StripeRust Wheat Management (StripeRustWM) showing the distribution of expected net return resulting from a single fungicide application.

and is likely to spread and become established in Victoria. In SA, the Centre for Crop and Disease Management (CCDM) researchers have identified resistance to fluxapyroxad (a member of the Succinate Dehydrogenase Inhibitors (SDHI) group of fungicides), the active ingredient in the seed treatment Systiva®, and tebuconazole. Subsequently these fungicides may no longer be reliable options for NFNB control (see section on fungicide resistance below for more details). While the initial discovery of resistance occurred on the Yorke Peninsula, SA, the extent of the distribution is likely to increase with time.

Fungicides will be an important part of NFNB control in susceptible varieties. Previous research has shown that two fungicide applications can be effective for NFNB management. Either seed applied Systiva® followed by foliar application at Z39-55, or two foliar applications at Z31 and Z39 or Z55 are effective. Earlier applications tend to be more effective in shorter season environments and later applications in longer, high rainfall environments. It is important to rotate fungicides with different modes of action to minimise the chance of resistance developing.

In general, susceptible crops with a yield potential of 5t/ha or more are at risk of substantial economic losses, especially during a wet spring. Experiments conducted in the Victorian Mallee and Wimmera during 2019 demonstrated that NFNB was severe, with up to 70% of leaf area affected at grain fill (Figure 3), up to 18% grain yield loss and reductions to grain plumpness (Tables 1, 2 and 3) in the very susceptible breeding line VB9613. The partially resistant varieties had less infection and grain yield loss than VB9613. RGT Planet⟨ᵸ⟩ is rated susceptible to very-susceptible (SVS), and had up to 11% infection and 5% grain yield loss while all other varieties had less than 5% leaf area infected at the end of the season. This illustrates that avoiding growing highly susceptible varieties, such as those rated as susceptible to very-susceptible (SVS), or worse, to NFNB, will significantly reduce potential losses and the need for fungicide intervention. In general, NFNB should be managed in susceptible varieties where disease levels are moderate and yield potential is above 5t/ha. It is also likely that NFNB can cause economic losses where yield potential is between 3 to 5t/ha and there are wet spring conditions. Experiments are being conducted during 2020 to investigate this further.

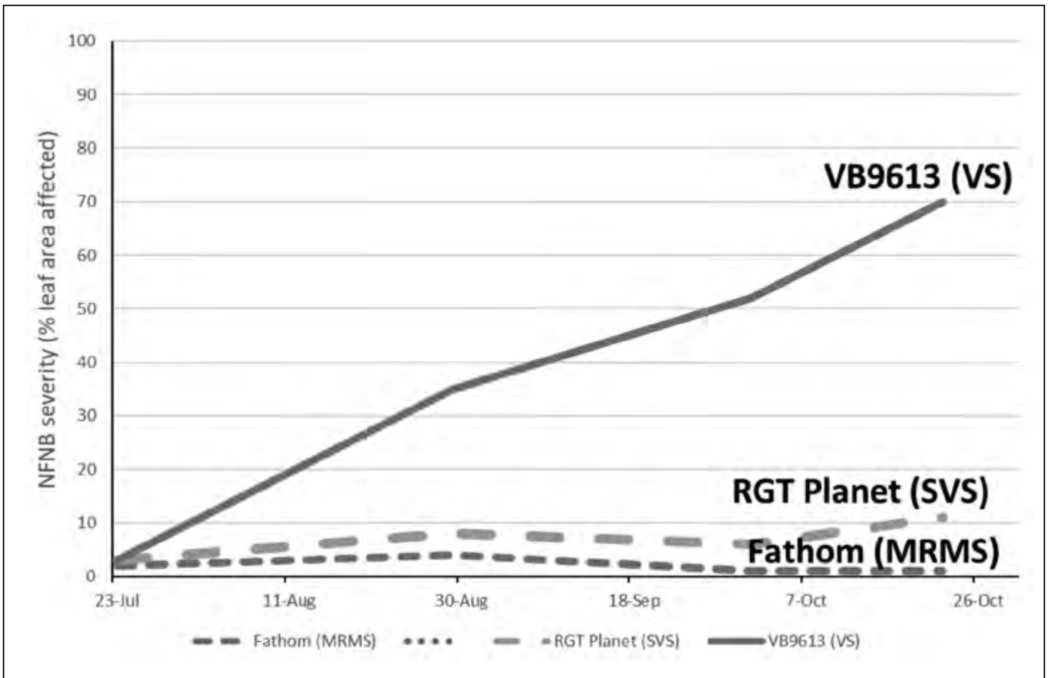

Figure 3. Severe net form of net blotch infection developed in breeding line VB9613, rated susceptible to very-susceptible (SVS), compared to moderate and low infection in RGT Planet⟨ᵸ⟩ (SVS) and Fathom⟨ᵸ⟩ moderately resistant to moderately susceptible (MRMS) at Birchip during 2019.

Table 1. Net form of net blotch severity (% leaf area affected) and grain yield of eight barley varieties grown at Birchip during 2019.

Variety	Rating#	Disease severity (%) 22 October 2019 (Z85)		Grain Yield (t/ha)		
		NFNB	SFNB	Dis.A	Fung.	% Loss
Banks(b)	MR	1	5	5.6	5.5*ns*	0
Fathom(b)	MRMS	1	0	5.3	5.4*ns*	2
Commander(b)	MS	1	5	4.9	5*ns*	2
SakuraStar(b)	MS	1	0	5.4	5.5*ns*	2
Spartacus CL(b)	MSS	1	10	6.2	6.4*ns*	3
Alestar(b)	S	3	0	5.3	5.6*	5
RGT Planet(b)	SVS	11	10	6.5	6.7 *ns*	3
VB9613	VS	70	0	4.2	5.1*	18
P=		<0.001	-	-	-	-
LSD (0.05)=		2.9	-	-	-	-

A Dis. = Disease - 1kg infected stubble, no fungicides; Fung. = no stubble, Systiva® + Prosaro® at Z31 and Z39.

* = Significant at 5%; ns = not statistically significant when the fungicide and disease treatments are compared.

\# rating = moderately resistant (MR), moderately susceptible (MS), moderately resistant – moderately susceptible (MRMS), moderately susceptible – susceptible (MSS), susceptible (S), susceptible – very susceptible (SVS), very susceptible (VS).

Table 2. Effect of net form of net blotch on grain quality for eight barley varieties grown at Birchip during 2019.

Variety	Rating#	Screenings (%<2.2mm)			Retention (%>2.5mm)		
		Dis.A	Fung.	% Increase	Dis.	Fung.	% Loss
Banks(b)	MR	3	5*ns*	0	76	77*ns*	1
Fathom(b)	MRMS	2	2*ns*	0	91	90*ns*	0
Commander(b)	MS	3	4*ns*	1	84	83*ns*	0
SakuraStar(b)	MS	5	4*ns*	1	76	79*ns*	3
Spartacus CL(b)	MSS	3	2*ns*	1	76	79*ns*	3
Alestar(b)	S	4	3*ns*	1	76	78*ns*	2
RGT Planet(b)	SVS	3	4*ns*	0	75	73*ns*	0
VB9613	VS	10	5*	5	28	45*	17

A Dis. = Disease - 1kg infected stubble, no fungicides; Fung. = no stubble, Systiva® + Prosaro® at Z31 and Z39.

* = Significant at 5%; ns = not statistically significant when the fungicide and disease treatments are compared.

\# rating = moderately resistant (MR), moderately susceptible (MS), moderately resistant – moderately susceptible (MRMS), moderately susceptible – susceptible (MSS), susceptible (S), susceptible – very susceptible (SVS), very susceptible (VS).

Table 3. Net form of net blotch severity, frost damage and grain yield of eight barley varieties grown at Horsham during 2019.

Variety	Rating#	NFNB severity (%LAA) 22 October 2019 Z85	Frost damage (%)	Grain yield (t/ha)		Loss (%)
				Dis.A	Fung.	
Banks(b)	MR	1	5	5.5	5.5	0
Fathom(b)	MRMS	1	5	6.3	6.5	3
Commander(b)	MS	3	30	5.7	5.5	0
SakuraStar(b)	MS	1	5	5.9	5.9	0
Spartacus CL(b)	MSS	1	2	6.3	6.4	2
Alestar(b)	S	2	8	5.2	5.0	0
RGT Planet(b)	SVS	9	2	5.7	6.0*	5
VB9613	VS	47	2	4.8	5.2**	8
P=		<0.001	-	-	-	
LSD (0.05)=		3.2	-	-	-	

A Dis. = Disease - 1kg infected stubble, no fungicides; Fung. = no stubble, Systiva® + Prosaro® at Z31 and Z39.

** = statistically significant at 5%, * = Significant at 5%; ns = not statistically significant when the fungicide and disease treatments are compared.

\# rating = moderately resistant (MR), moderately susceptible (MS), moderately resistant – moderately susceptible (MRMS), moderately susceptible – susceptible (MSS), susceptible (S), susceptible – very susceptible (SVS), very susceptible (VS).

Foliar diseases of oats

Foliar diseases are a major constraint on milling oat production in south eastern Australia. Surveys identified red leather leaf (RLL), caused by the fungus *Spermospora avenae*, as the most common and severe foliar disease in south eastern Australia. It is restricted to the medium and high rainfall zones as it is favoured by wet and cool conditions.

During 2019, bacterial blight was common across all rainfall zones but was generally at low levels that were unlikely to cause significant loss. However, given the right seasonal conditions there is potential for it to cause losses.

Experiments conducted in the Wimmera during 2019 demonstrated that RLL caused up to 13% (0.5t/ha) grain yield loss in susceptible varieties (Table 4). Yallara$^{\phi}$ was the worst affected, while Mitika$^{\phi}$ and Williams$^{\phi}$ were also affected. Growers should grow moderately susceptible (MS) or better rated varieties to reduce losses. Most of the infection was on the flag -2 leaves and lower. Greater losses are possible during wet weather conditions that favour greater infection on the top two leaves.

There are no fungicides registered for control of RLL in oats. We investigated fungicides registered for use in oats for potential suppression and control. We found that fungicides suppress RLL but do not provide complete control. Previous research showed that each foliar fungicide application provided 5-7% reduction in RLL severity in the Wimmera. Greater response has been observed in the high rainfall zone. This was illustrated by the fungicide treatment in Table 4 which shows up to 11% RLL infection following three applications of propiconazole. Previous research has shown that foliar fungicide applications at Z25 and Z31 are most effective as they coincide with early disease development, while application at Z39 can provide benefits during seasons with wet springs.

Growers should avoid sowing oats into paddocks with oat stubble from previous years as this is the main source of infection. RLL can also be seed-borne, so it is important to monitor all crops and apply fungicides if necessary.

Fungicide resistance

Fungicide resistance is an important issue for the management of diseases in cereals. During the last 20 years fungicides have provided cheap and reliable control of many fungal diseases, but their frequent use has resulted in a selection pressure which favours pathotypes that have mutations for fungicide resistance. Subsequently, there are increasing reports of diseases displaying reduced fungicide sensitivity and fungicide resistance. It is important that the agricultural industry adopts strategies that reduce reliance on fungicides to ensure their longevity.

During 2019, there were several reports of fungicide resistance in cereal diseases across Australia. The most significant was the identification of fungicide resistance in barley net form of net blotch (NFNB) to fluxapyroxad (a member of the SDHI group of fungicides) in the seed treatment Systiva®. This resistance was confirmed by the fungicide resistance researchers from the Centre for Crop and Disease Management at Curtin University in collaboration with SARDI in samples taken from multiple paddocks across the Yorke

Table 4. Red leather leaf (RLL) severity and grain yield of six milling oat varieties in response to disease and fungicide treatments near Horsham during 2019.

Variety	Rating#	Red leather leaf (RLL) severity (% leaf area affected)				
		16/8 Z32		Grain yield (t/ha)		
		Dis.[A]	Fung.	Dis	Fung	Loss (%)
Kowari$^{\phi}$	MS	14	7	4.2	4.2^{ns}	0
Bilby$^{\phi}$	MS	14	8	3.7	3.9^{ns}	5
Bannister$^{\phi}$	MSS	16	8	3.9	4.1^{ns}	5
Williams$^{\phi}$	MS	15	7	3.8	4.2*	9
Mitika$^{\phi}$	S	16	10	4.0	4.4*	9
Yallara$^{\phi}$	SVS	20	11	3.3	3.8*	13
P=		<0.001	0.034	-	-	-
LSD (0.05)=		2.138	2.629	-	-	-

[A] *Dis. = Disease - 1 kg infected stubble, no fungicides; Fung. = no stubble, propiconazole at Z25, Z31 and Z39.*

rating = moderately resistant (MR), moderately susceptible (MS), moderately resistant – moderately susceptible (MRMS), moderately susceptible – susceptible (MSS), susceptible (S), susceptible – very susceptible (SVS), very susceptible (VS).

Peninsula in South Australia. Whilst testing for resistance to SDHI fungicides, a very high level of resistance to tebuconazole (used as an indicator of resistance within the DMI group of fungicides) was also detected in all 15 paddocks tested across the YP. Testing so far has focused on the YP but given the widespread dispersal of airborne spores it is possible that spores of the dual-resistant pathotype of NFNB will have been dispersed during 2019 and may be present across a wider area, albeit at a low level during 2020. Further field testing is planned for 2020.

This development and spread of fungicide resistance for NFNB is likely to have been enhanced with the sowing of susceptible barley varieties into infected barley stubbles and the repeated use of fluxapyroxad (Systiva®) and a narrow range of DMI fungicides. This incidence highlights the importance of not becoming over-reliant on a single option for disease control.

The agricultural industry can slow the development of fungicide resistance and thus protect the longevity of the limited fungicides available by adopting the following disease management strategies;

- Use a range of control strategies to minimise disease development, including;
  - avoid growing highly susceptible cultivars
  - use crop rotation to avoid planting into paddocks with disease present
  - manage the green bridge for diseases such as mildew and rust.
- Use seed and/or fertiliser treatments, if available, to suppress early disease development.
- Avoid unnecessary fungicide use.
- Use fungicide mixtures formulated with more than one mode of action.
- Do not use the same active ingredient more than once within a season.
- Adhere to label recommendations.

New fact sheets

Several new fact sheets have been released recently that provide current and useful information for the management of diseases in cereals. Links to each of the new fact sheets can be found in the 'useful resources' section at the end of this report.

Cereal disease guide

The 2020 Cereal disease guide published by Agriculture Victoria provides current variety ratings for all recently released and commonly grown cereal varieties in Victoria, using the latest disease resistance ratings from the NVT. The ratings reflect the disease strains of importance in Victoria. As the strains of disease do change over time it is always important to consult a current version of the guide.

Crown rot

A new GRDC fact sheet has been published on the identification and control of crown rot. In seasons conducive to crown rot (such as those with a dry spring) losses greater than 20% are common in wheat crops grown in paddocks with medium to high crown rot levels. As there are no in-crop control options available, the fact sheet recommends the use of soil testing to identify risk prior to planting.

Root lesion nematode

The latest information on the management and control of root lesion nematodes has been published in a GRDC fact sheet. It highlights the advantages of using soil testing to determine nematode levels within paddocks to enable the planning of rotations to minimise losses.

Spot form of net blotch in barley

A fact sheet on the identification and management of spot form of net blotch in barley is due for release by GRDC in early 2020. This disease can cause yield losses greater than 20% in susceptible varieties during wet seasons, when crops are planted into paddocks with infected stubble. The fact sheet highlights the potential yield losses from the disease and the important control strategies to minimise losses.

Seed treatment guide

SARDI has published the 2020 guide to cereal seed treatments, which lists all the registered seed and fertiliser treatments available to assist with disease control.

Conclusion

In the absence of proactive disease control, yield losses due to diseases can be greater than 20%. Therefore, it is important to develop plans to effectively manage cereal diseases this season. Disease management plans should consider paddock and variety selection and, where the risk warrants it, the proactive use of fungicides that avoid overuse to protect their longevity.

Acknowledgements

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Thanks to Agriculture Victoria's cereal pathology team; Graham Exell, Jordan McDonald, Glenn Sluggett, Joshua Fanning, Jon Baker, Melissa Cook, Hari Dadu, Luise Sigel, Jennifer Cutajar and Winnie Liu Heang. Thanks also to the Birchip Cropping Group for field trials within the Victorian Mallee.

Useful resources

Current Victorian cereal disease guide:

http://agriculture.vic.gov.au/agriculture/pests-diseases-and-weeds/plant-diseases/grains-pulses-and-cereals/cereal-disease-guide

Root lesion nematode fact sheet:

https://grdc.com.au/root-lesion-nematode-southern

Crown rot fact sheet:

https://grdc.com.au/crown-rot-southern

Cereal seed treatment guide, 2020:

https://pir.sa.gov.au/__data/assets/pdf_file/0005/237920/Cereal_seed_treatments_2020.pdf

Spot form of net blotch fact sheet:

Check the GRDC web site for an early 2020 release.

Contact details

Grant Hollaway
Agriculture Victoria
Private Bag 260, Horsham VIC 3401
03 4344 3111
grant.hollaway@agriculture.vic.gov.au
@Grant_Hollaway

Mark McLean
Agriculture Victoria
Private Bag 260, Horsham VIC 3401
03 4344 3111
mark.s.mclean@agriculture.vic.gov.au
@msmclean777

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Notes

LOOK AROUND YOU.

1 in 5 people in rural Australia are currently experiencing mental health issues.

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The GRDC supports the mental wellbeing of Australian grain growers and their communities. Are you ok? If you or someone you know is experiencing mental health issues call *beyondblue* or Lifeline for 24/7 crisis support.

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www.beyondblue.org.au

beyondblue Depression. Anxiety.

Lifeline
13 11 14
www.lifeline.org.au

Lifeline 13 11 14

Looking for information on mental wellbeing? Information and support resources are available through:

www.ifarmwell.com.au An online toolkit specifically tailored to help growers cope with challenges, particularly things beyond their control (such as weather), and get the most out of every day.

www.blackdoginstitute.org.au The Black Dog Institute is a medical research institute that focuses on the identification, prevention and treatment of mental illness. Its website aims to lead you through the logical steps in seeking help for mood disorders, such as depression and bipolar disorder, and to provide you with information, resources and assessment tools.

www.crrmh.com.au The Centre for Rural & Remote Mental Health (CRRMH) provides leadership in rural and remote mental-health research, working closely with rural communities and partners to provide evidence-based service design, delivery and education.

Glove Box Guide to Mental Health
The *Glove Box Guide to Mental Health* includes stories, tips, and information about services to help connect rural communities and encourage conversations about mental health. Available online from CRRMH.

www.rrmh.com.au Rural & Remote Mental Health run workshops and training through its Rural Minds program, which is designed to raise mental health awareness and confidence, grow understanding and ensure information is embedded into agricultural and farming communities.

www.cores.org.au CORES™ (Community Response to Eliminating Suicide) is a community-based program that educates members of a local community on how to intervene when they encounter a person they believe may be suicidal.

www.headsup.org.au Heads Up is all about giving individuals and businesses tools to create more mentally healthy workplaces. Heads Up provides a wide range of resources, information and advice for individuals and organisations – designed to offer simple, practical and, importantly, achievable guidance. You can also create an action plan that is tailored for your business.

www.farmerhealth.org.au The National Centre for Farmer Health provides leadership to improve the health, wellbeing and safety of farm workers, their families and communities across Australia and serves to increase knowledge transfer between farmers, medical professionals, academics and students.

www.ruralhealth.org.au The National Rural Health Alliance produces a range of communication materials, including fact sheets and infographics, media releases and its flagship magazine *Partyline*.

ifarmwell growing farmers' wellbeing | Black Dog Institute | Centre for Rural & Remote Mental Health | CORES™

Rural & Remote Mental Health | Heads up Better mental health in the workplace | National Centre for Farmer Health | National Rural Health Alliance Ltd

P Level 4 | 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604 **T** +61 2 6166 4500 **F** +61 2 6166 4599 **E** grdc@grdc.com.au

Sustaining our herbicide options into the future

Christopher Preston.

School of Agriculture, Food & Wine, University of Adelaide.

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Keywords

- pre-emergent herbicide, annual ryegrass, broadleaf weeds.

Take home messages

- Resistance to pre-emergent herbicides is increasing across southern Australia.
- New pre-emergent herbicides are becoming available; however, it is vital that these are used appropriately to get the best results.
- Rotating pre-emergent herbicide modes of action and using other weed management practices will be essential to managing resistance to these new herbicides.

Resistance to pre-emergent herbicides in south-eastern Australia

Pre-emergent herbicides have become more important for the control of grass weeds, particularly annual ryegrass, in the past decade as resistance to post-emergent herbicides has increased. However, resistance to trifluralin is now common across many cropping regions of South Australia (SA) and Victoria (Vic) (Table 1). Worryingly, resistance to the Group J and K pre-emergent herbicides has also been detected in random weed surveys. In some parts of SA, resistance to triallate is also becoming common. This means that it will become more difficult to control annual ryegrass with the current suite of herbicides available.

New pre-emergent herbicides

There are several new pre-emergent herbicides coming to market in the next few years. As with previous recent introductions of pre-emergent herbicides, it is important to understand their best use in different environments and farming systems. Some of these products will be new modes of action, which will provide an opportunity to manage weeds with resistance to existing herbicides. However, it will be important to rotate these new herbicide modes of action to delay resistance.

Table 1. Resistance to pre-emergent herbicides in annual ryegrass populations from random surveys in South Australia and Victoria. Samples were considered resistant to a herbicide if more than 20% of individuals survived the herbicide application.

Herbicide	Trade name	South Australia				Victoria		
		Mid North	Mallee	Eyre Peninsula	South East	Wimmera/ Mallee	North East	Southern
		Samples resistant (%)						
Trifluralin	TriflurX®	62	39	34	41	31	0	2
Triallate	Avadex® Xtra	26	2	2	23	3	2	10
Prosulfocarb + S-metolachlor	Boxer Gold®	2	0	1	5	0	0	0
Prosulfocarb	Arcade®	2	0	1	5	-	1	0
Pyroxasulfone	Sakura®	0	1	0	5	0	0	0
Propyzamide	Edge®	0	0	0	0	0	0	0

Grass herbicides

Luximax

Luximax® from BASF is a new mode of action herbicide (currently Group Z), containing cinmethylin that is available from 2020. Luximax will be a pre-emergent herbicide for annual ryegrass control in wheat, but not durum. It will provide some suppression of brome grass and wild oats. In our trials, control of ryegrass is as good as Sakura®.

Cinmethylin has high water solubility and moderate binding to organic matter in soils. Cinmethylin will move readily into the soil with rainfall events but will be held up in soils with high organic matter. Less rainfall will be required to activate the herbicide similar to Boxer Gold® (prosulfocarb + S-metolachlor). Persistence of Luximax is generally good, but it degrades sufficiently quickly so that plant backs in subsequent years are not likely to be a problem.

Wheat is not inherently tolerant of cinmethylin, so positional selectivity (keeping the herbicide and the crop seed separate) is important. Knife-points and press-wheels are the only safe seeding system and the crop seed needs to be sown 3cm or deeper. Obtaining crop safety with Luximax will be challenging on light soils with low organic matter. Heavy rainfall after application can also see the herbicide move into the crop row and cause crop damage. Due to its behaviour, Luximax is not generally suitable for dry seeding conditions. Mixtures with trifluralin, triallate and prosulfocarb are good and can provide some additional ryegrass control; however, mixtures with Sakura, Boxer Gold or Dual Gold® are likely to cause crop damage and need to be avoided.

Overwatch™

Overwatch, active ingredient bixlozone, from FMC is a Group Q herbicide that will be available for 2021. Overwatch controls annual ryegrass and some broadleaf weeds and will be registered in wheat, barley and canola. Suppression of barley grass, brome grass and wild oats can occur.

Wheat is most tolerant to bixlozone, followed by barley and then canola. The safest use pattern will be incorporated by sowing (IBS) with knife-points and press wheels to maximise positional selectivity, particularly with canola. Some bleaching of the emerging crop occurs often, but in our trials, this has never resulted in yield loss. In situations where the crop grows poorly, for example, water logging, high root disease, etc., the crop may have more difficulty growing away from the initial bleaching effect.

The behaviour of Overwatch in the soil appears to be similar to Sakura. It needs moisture to activate and has low to moderate water solubility. The level of ryegrass control in our trials has been just behind Sakura. Mixtures with other herbicides can increase control levels and in our trials in the high rainfall zones, the mixture of Overwatch plus Sakura has been very good.

Ultro

Ultro, active ingredient carbetamide, from Adama is a Group E herbicide that will be available from 2021. Ultro will be registered for the control of annual ryegrass, barley grass and brome grass in all pulse crops.

Pulses are all tolerant of Ultro, so crop damage should be rare. Ultro provides the best control of annual ryegrass when used pre-emergent. Ultro has relatively high-water solubility, so is more effective on weeds like brome grass that tend to bury themselves in the soil. Persistence of Ultro is shorter than Sakura.

Persistence in the soil is medium; however, extended use of carbetamide in the pasture seed industry in the 1990s led to enhanced soil breakdown. This is unlikely to be a problem in grain production, as pulse crops are not grown every year. However, these soils also developed enhanced breakdown of propyzamide.

Devrinol-C

Devrinol-C, active ingredient napropamide, is a Group K herbicide from UPL registered in 2019. Devrinol-C is registered for annual grass weed control in canola.

Napropamide is not as water soluble as metazachlor (Butisan®) and has less movement through the soil. Canola has much greater tolerance to napropamide compared to metazachlor making its use much safer under adverse conditions. Devrinol-C offers an alternative pre-emergent herbicide to propyzamide or trifluralin for canola.

BAY167

BAY167 is an experimental product from Bayer. It will be a new mode of action, pre-emergent and early post-emergent herbicide for the control of grass and some broadleaf weeds in wheat and barley. Registration is expected in 2023.

The behaviour of this herbicide in the soil will be more similar to Sakura, compared to Boxer Gold. It will require more rainfall to activate and will have similar persistence to Sakura. It will most likely work best as a pre-emergent IBS herbicide. The timing of the early post-emergent application will be similar to Boxer Gold, at the 1 to 2-leaf stage of annual ryegrass. It will require more rainfall after application than Boxer Gold does, so the post-emergent application will be more suited to higher rainfall regions.

Broadleaf herbicides

Callisto®

Callisto, active ingredient, mesotrione is a pre-emergent Group H herbicide from Syngenta with expected registration in 2020. It will be registered as for IBS, knife-point press wheel use in wheat and barley. It will control a range of broadleaf herbicides including brassicas, legumes, capeweed and thistles.

Wheat is more tolerant than barley, **and in both cases**, positional selectivity is important for crop safety. Mesotrione has high water solubility and medium mobility in soils. High rainfall resulting in furrow wall collapse could result in crop damage. Callisto has moderate persistence with plant backs of only nine months, provided 250mm of rainfall has occurred. Callisto offers an alternative to post-emergent Group H herbicide mixtures, where early weed control is important.

Reflex®

Reflex, active ingredient fomesafen, is a Group G herbicide from Syngenta with expected registration in 2021. It will be registered pre-emergent and post-sowing pre-emergent (PSPE) in pulse crops for control of broadleaf weeds; IBS only in lentils. It will have similar weed spectrum to Terrain®, but will likely provide better control of brassicas, sowthistle and prickly lettuce.

Fomesafen has more water solubility than flumioxazin (Terrain), so will be more mobile in the soil. It does not bind tightly to organic matter. Pulse crop safety is good, except for lentils, which are most sensitive. Care will be needed in lentils on light soils with low organic matter. Fomesafen persistence is good; however, plant backs are expected to be nine months provided 250mm rainfall has occurred.

Voraxor

Voraxor, from BASF, contains the active ingredients trifludimoxazin and saflufenacil, which are both Group G herbicides. Voraxor will provide broadleaf weed control and some annual ryegrass control as a pre-emergent herbicide in cereals. It is expected to be registered in 2021.

Voraxor is a little more mobile in the soil compared to Reflex® and considerably more than Terrain. Voraxor will offer a broader spectrum of broadleaf weed control compared to Terrain and more annual ryegrass control. However, annual ryegrass control will not be as good as with current annual ryegrass pre-emergent standards. This means that it will be best used where broadleaf weeds are the main problem and annual ryegrass populations are very low. Grass pre-emergent herbicides cannot be tank mixed with Voraxor and will have to go out as a separate application.

Managing resistance to the new pre-emergent herbicides

The availability of new modes of action, particularly for annual ryegrass control, is a valuable aid to maintaining no-till in grain production. However, overreliance on any herbicide mode of action can lead to resistance. Some of the annual ryegrass populations with widespread resistance to other herbicides already have low level resistance to napropamide and bixlozone. In addition, there are an increasing number of Group H and Group G herbicides becoming available. Care needs to be taken to rotate herbicide modes of action through the cropping rotation to delay the onset of resistance. Other weed management practices such as crop competition, crop topping and harvest weed seed control should be employed where appropriate.

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Contact details

Dr Chris Preston
School of Agriculture, Food & Wine
University of Adelaide
0488 404 120
christopher.preston@adelaide.edu.au

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Notes

Addressing the yield gap – local hyper-yielding project

Jon Midwood.

SFS.

Notes

Contact details

Jon Midwood
jmidwood@sfs.org.au

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GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

P Level 4 | 4 National Circuit, Barton ACT 2600 | PO Box 5367, Kingston ACT 2604 **T** +61 2 6166 4500 **F** +61 2 6166 4599
E grdc@grdc.com.au @theGRDC

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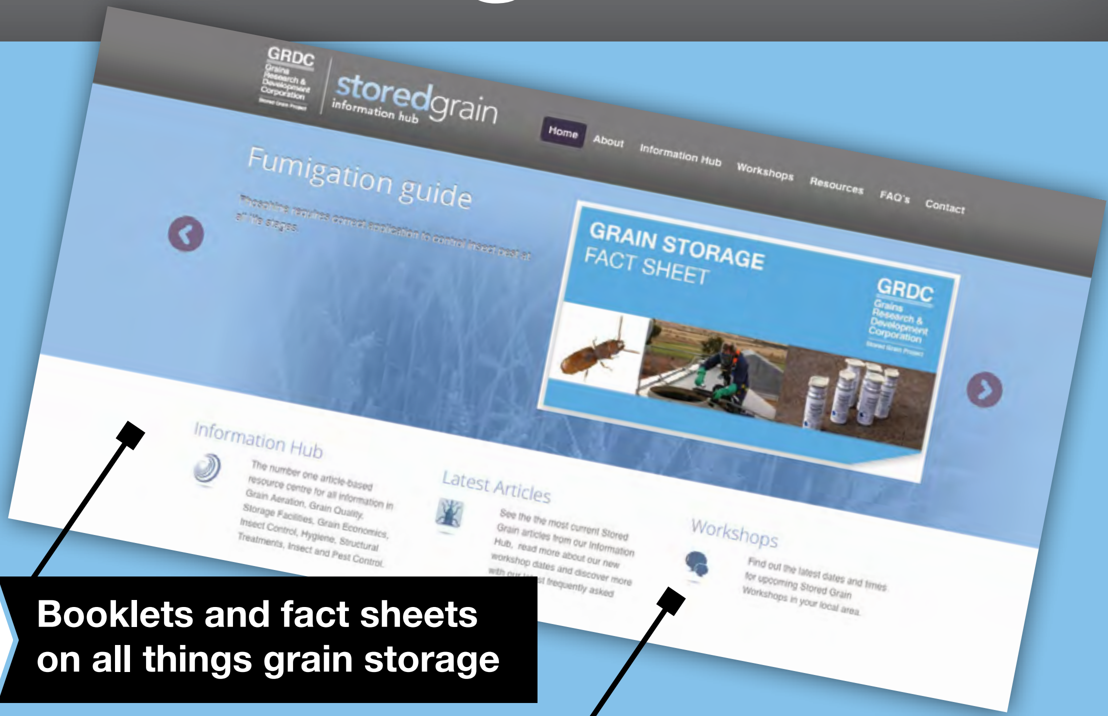

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THE 2017-2020 GRDC SOUTHERN REGIONAL PANEL

JANUARY 2020

CHAIR - JOHN BENNETT

Based at Lawloit, between Nhill and Kaniva in Victoria's West Wimmera, John, his wife Allison and family run a mixed farming operation across diverse soil types. The farming system is 70 to 80 percent cropping, with cereals, oilseeds, legumes and hay grown. John believes in the science-based research, new technologies and opportunities that the GRDC delivers to graingrowers. He wants to see RD&E investments promote resilient and sustainable farming systems that deliver more profit to growers and ultimately make agriculture an exciting career path for young people.

M 0429 919 223 E john.bennett5@bigpond.com

DEPUTY CHAIR - MIKE MCLAUGHLIN

Mike is a researcher with the University of Adelaide, based at the Waite campus in South Australia. He specialises in soil fertility and crop nutrition, contaminants in fertilisers, wastes, soils and crops. Mike manages the Fertiliser Technology Research Centre at the University of Adelaide and has a wide network of contacts and collaborators nationally and internationally in the fertiliser industry and in soil fertility research.

M 0434 765 574
E michael.mclaughlin@adelaide.edu.au

PETER KUHLMANN

Peter is a farmer at Mudamuckla near Ceduna on South Australia's Western Eyre Peninsula. He uses liquid fertiliser, no-till and variable rate technology to assist in the challenge of dealing with low rainfall and subsoil constraints. Peter has been a board member of and chaired the Eyre Peninsula Agricultural Research Foundation and the South Australian Grain Industry Trust.

M 0428 258 032 E mudabie@bigpond.com

JON MIDWOOD

Jon has worked in agriculture for the past three decades, both in the UK and in Australia. In 2004 he moved to Geelong, Victoria, and managed Grainsearch, a grower-funded company evaluating European wheat and barley varieties for the high rainfall zone. In 2007, his consultancy managed the commercial contract trials for Southern Farming Systems (SFS). In 2010 he became Chief Executive of SFS, which has five branches covering southern Victoria and Tasmania. In 2012, Jon became a member of the GRDC's HRZ Regional Cropping Solutions Network.

M 0400 666 434 E jmidwood@sfs.org.au

FIONA MARSHALL

Fiona has been farming with her husband Craig for 21 years at Mulwala in the Southern Riverina. They are broadacre, dryland grain producers and also operate a sheep enterprise. Fiona has a background in applied science and education and is currently serving as a committee member of Riverine Plains Inc, an independent farming systems group. She is passionate about improving the profile and profitability of Australian grain growers.

M 0427 324 123 E redbank615@bigpond.com

LOUISE FLOHR

Lou is a farmer based at Lameroo in the Southern Mallee of South Australia. Along with her parents and partner, she runs a mixed farming enterprise including export oaten hay, wheat, barley a variety of legumes and a self-replacing Merino flock. After graduating Lou spent 3 years as a sales agronomist where she gained valuable on-farm experience about the retail industry and then returned to her home town of Lameroo. She started her own consultancy business three years ago and is passionate about upskilling women working on farms.

M 0429 083 927 E flohrlouise@gmail.com

RICHARD MURDOCH

Richard along with wife Lee-Anne, son Will and staff, grow wheat, canola, lentils and faba beans on some challenging soil types at Warooka on South Australia's Yorke Peninsula. They also operate a self-replacing Murray Grey cattle herd and Merino sheep flock. Sharing knowledge and strategies with the next generation is important to Richard whose passion for agriculture has extended beyond the farm to include involvement in the Agricultural Bureau of SA, Advisory Board of Agriculture SA, Agribusiness Council of Australia SA, the YP Alkaline Soils Group and grain marketing groups.

M 0419 842 419 E tuckokcowie@internode.on.net

MICHAEL CHILVERS

Michael runs a collaborative family farming enterprise at Nile in the Northern Midlands of Tasmania (with property also in northern NSW) having transitioned the business from a dryland grazing enterprise to an intensive mixed farming enterprise. He has a broad range of experience from resource management, strategic planning and risk profiling to human resource management and operational logistics, and has served as a member of the the High Rainfall Zone Regional Cropping Solutions Network for the past seven years.

M 0409 974 556 E fchilvers@bigpond.com

KATE WILSON

Kate is a partner in a large grain producing operation in Victoria's Southern Mallee region. Kate and husband Grant are fourth generation farmers producing wheat, canola, lentils, lupins and field peas. Kate has been an agronomic consultant for more than 20 years, servicing clients throughout the Mallee and northern Wimmera. Having witnessed and implemented much change in farming practices over the past two decades, Kate is passionate about RD&E to bring about positive practice change to growers.

M 0427 571 360 E kate.wilson@agrivision.net.au

ANDREW RUSSELL

Andrew is a forth generation grain grower and is currently the Managing Director and Shareholder of Lilliput AG and a Director and Shareholder of the affiliated Baker Seed Co - a family owned farming and seed cleaning business. He manages the family farm in the Rutherglen area, a 2,500 ha mixed cropping enterprise and also runs 2000 cross bred ewes. Lilliput AG consists of wheat, canola, lupin, faba bean, triticale and oats and clover for seed, along with hay cropping operations. Andrew has been a member of GRDC's Medium Rainfall Zone Regional Cropping Solutions Network and has a passion for rural communities, sustainable and profitable agriculture and small business resilience.

M 0417 401 004 E arussell@lilliput-ag.com.au

DR NICOLE JENSEN

Nicole Jensen is GRDC General Manager for the newly created Genetics and Enabling Technologies business group. Nicole brings a wealth of experience in plant breeding and related activities arising from several roles she has held in Australia and internationally in the seed industry including positions as Supply Innovation Lead with the Climate Corporation - Monsanto's digital agricultural flagship, Global Trait Integration Breeding Lead for Monsanto.

T 02 6166 4500 E Nicole.Jensen@grdc.com.au

T +61 8 8198 8407
P Grains Research and Development Corporation (GRDC) | Level 1 | 187 Fullarton Road, Dulwich 5065, South Australia

KEY CONTACTS

GRDC GRAINS RESEARCH & DEVELOPMENT CORPORATION

SOUTHERN REGION

ADELAIDE
Level 1
187 Fullarton Road
DULWICH SA 5065

P: +61 8 8198 8400
southern@grdc.com.au

OPERATIONS GROUP

SENIOR REGIONAL MANAGER
Craig Ruchs
Craig.Ruchs@grdc.com.au
M: +61 4 7771 0813

BUSINESS SUPPORT TEAM LEADER
Amanda Kendall
Amanda.Kendall@grdc.com.au
P: +61 8 8198 8402

CONTRACT AND TEAM ADMINISTRATOR
Claire West
Claire.West@grdc.com.au
P: +61 8 8198 8401

CONTRACT ADMINISTRATOR
Mark Waterhouse
Mark.Waterhouse@grdc.com.au
P: +61 8 8198 8406

APPLIED RESEARCH AND DEVELOPMENT GROUP

MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS
Stephen Loss
Stephen.Loss@grdc.com.au
M: +61 4 0841 2453

MANAGER AGRONOMY, SOILS, NUTRITION AND FARMING SYSTEMS
Allison Pearson
Allison.Pearson@grdc.com.au
M: +61 4 1887 4748

MANAGER WEEDS (NATIONAL)
Jason Emms
Jason.Emms@grdc.com.au
M: +61 4 3954 9950

CROP PROTECTION MANAGER SOUTH
Ruth Peek
Ruth.Peek@grdc.com.au
M: +61 4 5553 4040

GENETICS AND ENABLING TECHNOLOGIES GROUP

SENIOR MANAGER ENABLING TECHNOLOGIES
Tom Giles
Tom.Giles@grdc.com.au
M: +61 4 1788 9860

SENIOR MANAGER NATIONAL VARIETY TRIALS
Sean Coffey
Sean.Coffey@grdc.com.au
M: +61 4 2865 2226

MANAGER NATIONAL VARIETY TRIALS SOUTH
Rob Wheeler
Rob.Wheeler@grdc.com.au
M: +61 4 0114 8935

MANAGER NATIONAL VARIETY TRIALS SYSTEMS
Neale Sutton
Neale.Sutton@grdc.com.au
M: +61 4 3857 9992

MANAGER RESEARCH PLATFORMS
Trevor Garnett
Trevor.Garnett@grdc.com.au
M: +61 4 5790 6770

NATIONAL VARIETY TRIALS OFFICER
Ben O'Connor
Ben.O'Connor@grdc.com.au
M: +61 4 9988 7749

CONTRACT ADMINISTRATOR
Cindy Hall
Cindy.Hall@grdc.com.au
P: +61 8 8198 8407

GROWER EXTENSION AND COMMUNICATIONS GROUP

GROWER RELATIONS MANAGER
Courtney Ramsey
Courtney.Ramsey@grdc.com.au
M: +61 4 2827 4018

GROWER RELATIONS MANAGER
Randall Wilksch
Randall.Wilksch@grdc.com.au
M: +61 4 3776 9098

GROWER RELATIONS MANAGER
Tom Blake
Tom.Blake@grdc.com.au
M: +61 4 1889 3186

COMMUNICATIONS MANAGER
Sharon Watt
Sharon.Watt@grdc.com.au
M: +61 4 0967 5100

BUSINESS AND COMMERCIAL GROUP

ACTING GM – BUSINESS DEVELOPMENT AND ECONOMICS GROUP
Ron Osmond
Ron.Osmond@grdc.com.au
M: +61 4 000 2640

MANAGER COMMERCIALISATION
Fernando Felquer
Fernando.Felquer@grdc.com.au
M: +61 4 1351 1412

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CONTACT:
Russell Burns
russell.burns@sa.gov.au
0401 122 115

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- The local GRDC Grains Research Update planning committee including both government and private consultants and GRDC representatives.

- Partnering organisation: SFS

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2020 Bannockburn GRDC Grains Research Update Evaluation

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For each presentation you attended, please rate the content relevance and presentation quality on a scale of 0 to 10 by placing a number in the box (**10 = totally satisfactory, 0 = totally unsatisfactory**).

3. Breaking the big yield constraints – where to next? ***James Hunt***

Content relevance /10 Presentation quality /10

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4. Hitting production targets in the UK amidst a highly regulated environment: ***Keith Norman***

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5. Crop doctor - cereal disease update: ***Grant Hollaway***

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6. Integrating new chemistries in the field: ***Chris Preston***

Content relevance /10 Presentation quality /10

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7. Addressing the yield gap in the High Rainfall Zone: ***Jon Midwood and Keith Norman***

Content relevance ☐ /10 Presentation quality ☐ /10

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8. Please describe at least one new strategy you will undertake as a result of attending this Update event

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