CROP SCIENCE SOCIETY
OF SA INCORPORATED

Welcome to the March issue of the Crop Science Society of SA newsletter

Dear CSSSA Members,

Welcome to the March issue of the Crop Science Society of SA.

In this month's newsletter we explore:

- Member in focus – Mark HIll
- Characterising the optimal flowering period for the Murray Plains
- Max Tate's quest for a low toxin vetch

We hope you are keeping well. Please contact us if you have any requests for content of information.

Kind regards,

Dan Petersen
President, Crop Science Society of South Australia

Member in focus – Mark Hill

I have had the privilege for the past 54 years of farming our property (Gilberside) near Tarlee, which has been held in our family since 1874.

The sale of our breeding ewes last year saw a transition away from our emphasis on prime lamb production using Gilberside bred Poll Dorset sires. I am now planning on concentrating on our cattle production on un-arable Tarlee river flats, while the rest of the property will be continuously cropped. As I am not getting any younger, I am trying to streamline the operation so I can spend more time off farm.

Aside from my farm, my passions are my family and windsurfing. My wife Pam and I have three grown up children that all have professional jobs, while we have five grandsons that would all take over the farm tomorrow if they were allowed to leave primary school! I particularly enjoy visiting the Australian coastline at every opportunity I have to windsurf.

I was a foundation member when Crop Science started back in 1975, with John Lush the inaugural Chairman. I was fortunate to Chair for a few years in the 90's. Combines and cultivation was the go back then, with Treflan and Roundup fairly new on the block. Tarlee soils have been farmed for a long time and the majority are heavy red clay loams, which demand more respect than the cultivate and bash style of farming. Dad and I started full stubble retention in the early 70's, with many variations of smashing stubbles using tyres, harrows, slashing, disc ploughing and rolling. We had various modifications to combines to aid trash clearance, moving to a shearer 4150 in the 80's and 90's to our current Horwood Scaribar with 10"spacings and an arrow tyne pattern to handle 4-6 tonne stubbles with ease, as long as they are not much more than 12" high. I have been direct drilling all crops for over 40 years now with great enjoyment, maintaining as much cover as possible, with the soil getting much more friable and water use efficiency improving most years. For the first 20 years, I applied tungsten to various points we made or purchased. I have been using Ag Point DD points for the past 20 years.

Crop Science was and still is a great way to interact with farmers, scientists, researchers and agronomists to challenge us all to be better at crop production, as well as looking after the land. Meetings originally alternated monthly between Waite and Roseworthy with 80 to 100 people common at all meetings. Car loads came from the Upper SE, Mallee, Upper and Lower North, YP and sometimes EP. The annual bus trip in Spring lead by the late Tony Rathjen and his little shovel was always a highlight.

Sadly, crowds are down at meetings these days. Instead, busy farmers are paying agronomists for customised advice best suited to their operation, which has reduced the need to attend meetings. I very much still enjoy getting to Crop Science meetings where I can to interact with very interesting and switched on people to discuss and hear the latest in the Ag World!

Happy Farming
Mark Hill

Characterising the optimal flowering period for the Murray Plains

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SAGIT project code: S/UA1021

Keywords

- optimal flowering period, flowering time, phenology, crop development, wheat, barley

Take home messages

- Preliminary modelling suggests the optimal flowering period (OFP) for wheat at Palmer, South Australia is between the 27th August and 13th September.
- Current maturity ranges in wheat varieties can be used to achieve flowering within the OFP from different sowing times in the Murray Plains.
- Barley outyielded wheat across all germination dates in 2021.
- Slow spring wheats outperformed winter wheats from a mid-April germination date in the Murray Plains.

Background

Flowering time is an important determinant of final grain yield for cereals. For crops to maximise seed size and number (potential yield), cereals must first establish, develop biomass and then flower at a time that coincides with optimal seasonal conditions (Fischer, 1985; Trethowan, 2014; Sadras and Dreccer, 2015). A number of environmental stresses can cause sub-optimal flowering conditions which include, but are not limited to, frost, heat and drought. The optimal flowering period (OFP) is defined as the period where the combined environmental stress is limited, and where grain yield potential is maximised.

The Murray Plains is a cropping region in South Australia stretching from Murray Bridge in the south to Truro in the north, flanked by the Mount Lofty Ranges to the west and the River Murray to the east. It is a unique environment due to varying soil types and rainfall patterns. The Mount Lofty Ranges creates a rain shadow for the area leading to variable rainfall totals. Due to this variability in rainfall, it is often important to take advantage of early sowing opportunities in this region when they arise.

This project aims to extend previous findings and produce locally relevant information on early sowing, flowering time and the OFP to increase grower knowledge and crop production in the Murray Plains region.

Methods

In 2021, a field trial was established 4 km east of Palmer on the Murray Plains. The experiment consisted of commercially available wheat and barley varieties with different maturities (Table 1). All varieties were sown on two dates but with three different germination dates due to seasonal conditions. The first sowing date was the 20th of April, with 10mm of supplementary in-furrow irrigation applied through pressurised dripper hose to ensure plant establishment. The second sowing date was the 31st of May. Due to the lack of significant opening rainfall to stimulate germination, half of the experiment sown on this date was irrigated to ensure establishment. The final half was left 'dry sown' and germinated on the next significant rainfall event of 15mm on the 10th of June. Good winter rainfall occurred until the end of winter where there was again low rainfall until October causing spring drought stress (Figure 1). There was a combination of germination dates and crop maturities with the aim of producing a large spread in flowering time and to test the suitability of slower developing variety types with early sowing in the region. The field trial was statistically designed and analysed in a split-plot design with 3 replicates. Nutrition, weeds, pests and diseases were managed using grower practice and as to not limit yield.

Table 1 The (a) wheat and (b) barley varieties evaluated in the field trial at Palmer with their relative maturity types.

(a)

Variety	Maturity Group	Released
Vixen	Quick	2018
Ballista	Quick-Mid	2020
Scepter	Mid	2015
Rockstar	Mid-Slow	2019
Sheriff CL Plus	Mid-Slow	2018
Valiant CL Plus	Slow	2021
Denison	Slow	2020
Longsword	Quick Winter	2017
DS Bennett	Mid Winter	2018

(b)

Variety	Maturity Group	Released
Beast	Very Quick	2020
Commodus CL	Very Quick	2021
Spartacus CL	Very Quick	2016
Maximus CL	Very Quick	2020
Compass	Very Quick	2015
RGT Planet	Quick	2017

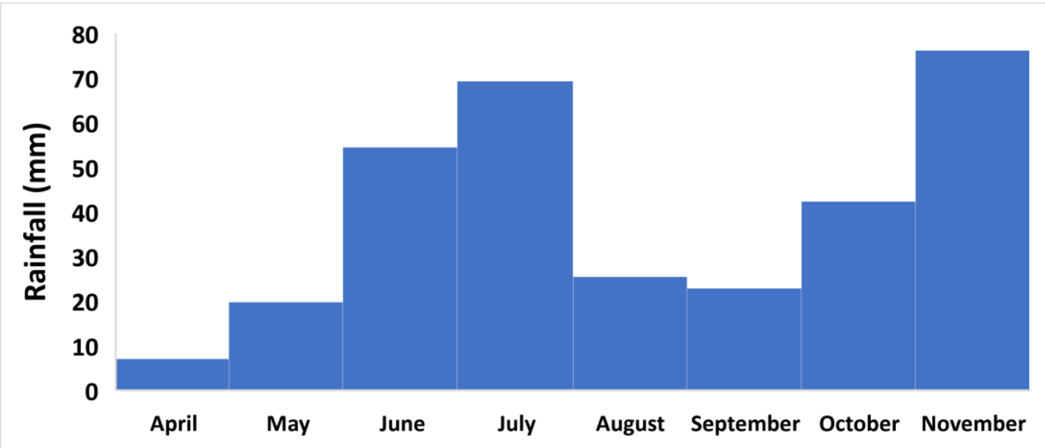


Figure 1 The growing season rainfall recorded for each month at the field site at Palmer with an ATMOS 41

Modelling of the OFP was completed using the crop modelling program APSIM Classic 7.10. The methodology for the creation of the OFP followed methods by Flohr et al. (2017), over a 40 year period from 1980 – 2020 utilising climatic data from SILO Longpaddock patch-point (-34.85, 139.20) and soil hard loam over red clay (463). APSIM-Manager was used to sow a wheat crop of Mace (quick-mid) every 3 days between the 1st of April till the 29th July. APSIM is limited by an inability to accurately predict yield penalties due to frost and heat, therefore the impact of frost and heat on yield was estimated based on methodology described by Bell et al. (2015). The OFP was characterised by calculating a 15-day rolling average of the frost and heat limited yield, with the OFP equalling the days where yield was ≥ 95% of the maximum frost and heat limited yield.

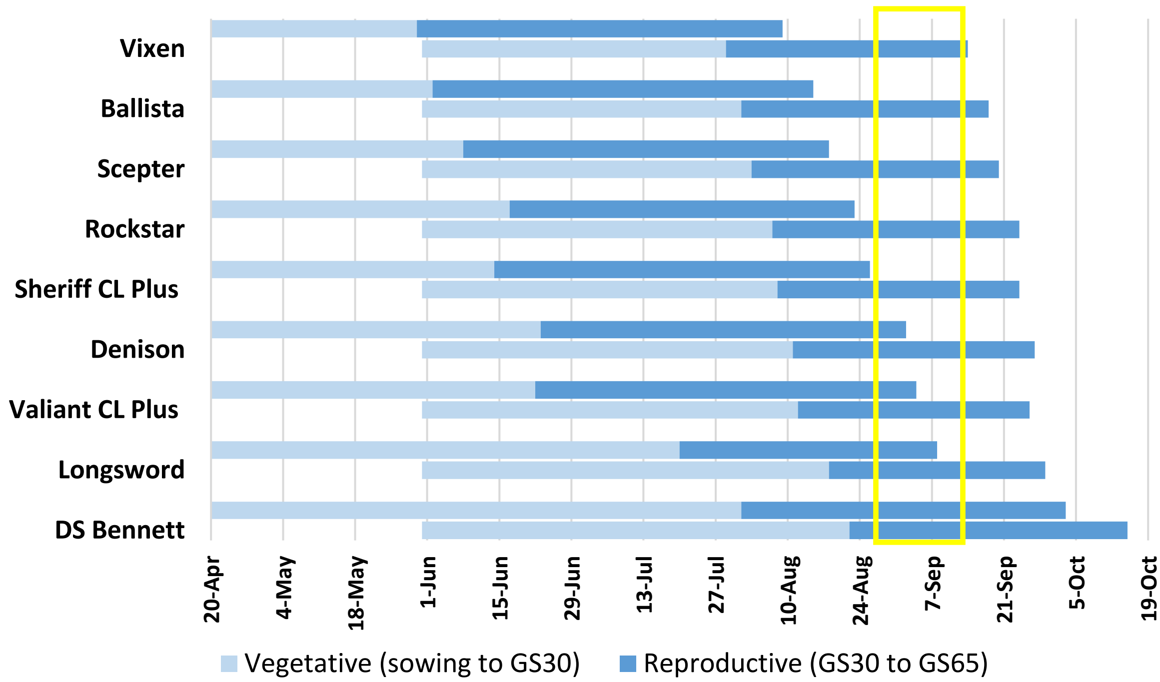
Results

Germination time influence on crop phenology

The timing of germination had a large influence on the relative vegetative (sowing to GS30) and reproductive (GS30 to GS65) phases of wheat development. Earlier germination generally increased the duration of the reproductive phase, while shortening the vegetative phase, especially for the quicker developing spring types of wheat (Figure 2). From the 31st May germination, GS30 occurred later near the end of winter, when daily temperatures were starting to increase again. This shortened the reproductive phase, which is likely one factor that reduced grain yields in the later germinating plants. From the 20th

April germination, longer season springs (Denison, Valiant CL Plus) and quick winters (Longsword) were found to be well adapted to flower within the OFP for Palmer (Figure 2). The vernalisation requirement of winters before progressing to reproductive development is evident, reaching GS30 in late July, which was a month later for Longsword compared to the slow spring Denison. The 31st of May germination was still too late by a couple of days for the fastest variety Vixen to flower within the OFP (Figure 2). There was a large difference in the relative time to flowering across quick (Vixen) to slow (Valiant CL Plus) springs between 20th April (26 days) and 31st May (12 days) germinations. This demonstrated the effect of late season warm temperatures on spring varieties (regulated by temperature), which when germinating late, developed quicker and rushed through to flowering.

Figure 2 A schematic showing the relative duration of the vegetative (sowing to early stem elongation) and reproductive (stem elongation to flowering) growth stages of each wheat variety at the Palmer field site. Two bars are shown for each variety representing two germination times of the 20th April and 31st May. The yellow box represents the preliminary optimal flowering period for wheat at Palmer in the Murray Plains from 27th August to 13th September.



Early sown barley responded similarly to early sown wheat, with an extended reproductive phase across varieties (Figure 3). When germinating late on the 31st May, the reproductive phase of barley was significantly shorter in comparison to earlier germination on the 20th April. Although later sowing did extend the vegetative phase of development. One key point evident in Figure 3, is that there is not the range in flowering time or phenology across current elite Australian barley varieties as oberved in wheat. There was only a difference of less than 2 weeks across either germination date. When comparing wheat and barley, Scepter sown early reached flowering earlier than Compass. However, with later germination dates, this swapped around with Compass flowering earlier than Scepter.

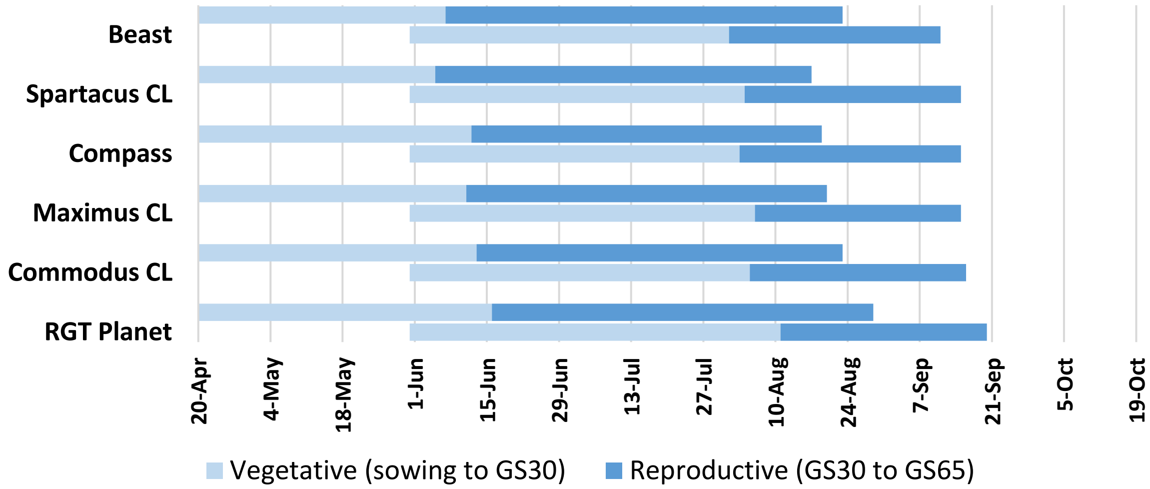


Figure 3 A schematic showing the relative duration of the vegetative (sowing to early stem elongation) and reproductive (stem elongation to flowering) growth stages of each barley variety at the Palmer field site. Two bars are shown for each variety representing two germination times of the 20th April and 31st May.

Grain yield across germination dates

Earlier germination dates increased grain yield for all barley varieties and for most wheat varieties (Table 2). Barley was the higher yielding crop type in 2021, particularly from the April germination date. The vigorous plant-type habits of Compass and Beast proved to be the standouts across germination dates. This suggested that, in the absence of frost, early sown barley is a viable option in the Murray Plains. For early sown wheat, Denison (slow spring) was a standout from the 20th April germination date. Denison significantly outyielded the winter development types, suggesting slow spring wheats may be a better option for early sowing from this initial year of trial data. However, early sown Scepter still performed well in the absence of frost, with grain yield similar to Denison. Late October and November rain significantly increased the grain yield of the late sown DS Bennett, which flowered very late (15th October). No other variety developed slow enough to make use of this late rain. Although late sowing of slow developing varieties is not recommended and that significant late season rain is historically very unlikely in the LRZ, it demonstrates how different crop variety phenologies can be used in farming systems to spread risk.

Table 2 The mean grain yield for each variety of (a) wheat and (b) barley at three germination dates (20th April, 31st May, 10th June) with green indicating above average, yellow on average and red below average.

(a)

Site mean yield: **2.88 t/ha**	Germination Date 20-Apr	31-May	10-Jun
Vixen	2.88	3.34	2.55
Ballista	3.26	3.12	2.94
Scepter	3.46	3.05	2.95
Rockstar	3.51	2.93	2.43
Sheriff CL Plus	3.39	2.72	2.33
Denison	3.59	2.88	2.93
Valiant CL Plus	2.77	2.49	2.34
Longsword	2.65	2.04	1.97
DS Bennett	2.87	3.29	3.07
p-value	<0.001		
LSD (*p*≤0.05)	0.366		

(b)

Site mean yield: **3.6 t/ha**	Germination Date 20-Apr	31-May	10-Jun
Beast	4.47	3.97	3.65
Compass	4.61	3.98	3.38
Commodus CL	4.32	4.02	3.14
Spartacus CL	3.71	3.45	2.81
Maximus CL	4	3.54	2.82
RGT Planet	3.93	2.6	2.48
p-value	0.017		
LSD (*p*≤0.05)	0.486		

Defining the Optimal Flowering Period

The preliminary modelling is suggesting that the OFP for wheat at Palmer occurs between the 27th August to 13th September (Figure 4). Flohr et al. (2017) characterised the OFP for a number of locations across SA, with Palmer being most similar to Lameroo (28th August to 20th September). The Palmer OFP is likely to be most influenced by soil water availability leading to a shorter OFP. This is driven by the variable rainfall pattern of the Murray Plains and also the heavier soil type leading to higher wilting points. 2021 was a prime example of spring drought conditions in September (Figure 4), which is consistent with the modelling.

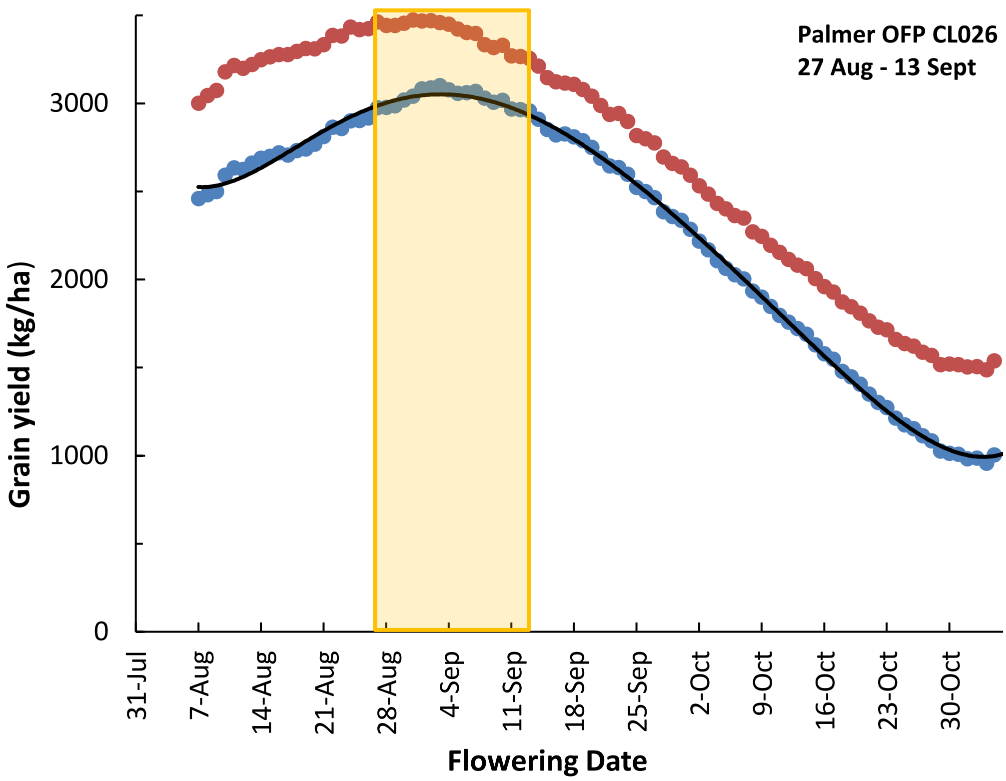


Figure 4 A preliminary draft of the optimal flowering period (OFP) for a quick-mid wheat variety Mace at Palmer in the Murray Plains. The blue dots represent the frost, heat and drought 15 day running mean yield with the red dots showing the water limited maximum potential yield. The yellow highlighted box indicates the duration of the OFP which is determined by 95% of the maximum yield from 40 seasons (1980-2020) and goes from the 27th August to 13th September.

A comparison of field results showed a correlation between flowering date and grain yield for 2021. The peak grain yield at Palmer was achieved when flowering occurred on the 2nd of September and this date is within the modelled OFP. There was some variation at the end of the season with late sown DS Bennett flowering in the middle of October and being able to utilise the late season rainfall during grain fill to substantially increase grain yield. The development of an APSIM barley OFP model is still in progress. Although, early indications using the seasonal yield and flowering data (Figure 5) suggests the OFP for barley may be earlier than the wheat. Head samples were collected from each plot and analysed but no frost induced sterility was observed. The Murray Plains is prone to frost events during flowering that can affect yield. This would affect the results and curve shown in Figure 5 and reduce yield of varieties flowering in early to mid-August.

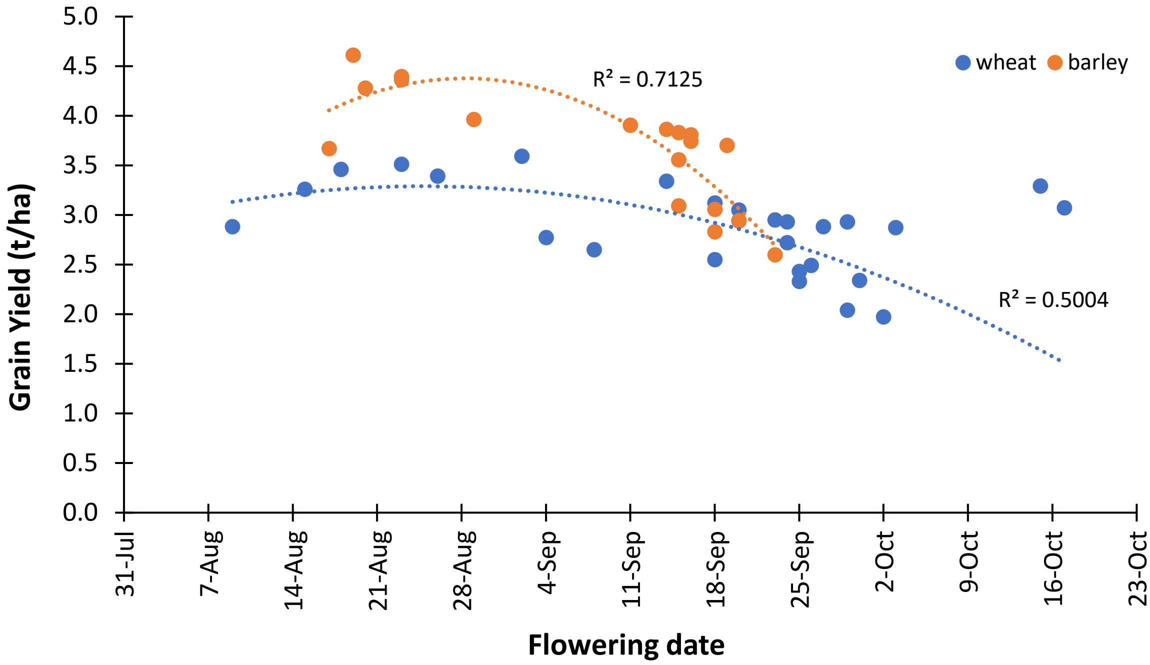


Figure 5 A comparison of the relative wheat and barley grain yield of every variety and their respective flowering dates at Palmer in 2021.

Conclusions

The current diversity in crop maturities available in different wheat varieties allows for a range in sowing dates. Flowering can still be achieved within the OFP for slow springs and quick winter wheats that germinate on the 20th April. However, the slow spring wheats outyielded the winter wheats and these initial results suggests they seem to be a better option when early sowing. The absence of significant frost events in the season allowed early sown quick developing barley varieties to yield well, suggesting this is still a good option in the low rainfall zone. Flowering dates and peak yield for the 2021 season correlated well with the preliminary modelling for OFP at Palmer. Further modelling and field data is required to validate initial trends and will be undertaken in 2022.

Acknowledgements

The authors would like to thank the South Australian Grain Industry Trust (SAGIT) for funding the project as well as the support from the University of Adelaide and South Australian Research and Development Institute (SARDI). The authors would like to acknowledge the support and extension opportunities for the project from the Murray Plains Farmers Group and the SARDI Waite agronomy group for trial technical support.

Max Tate's quest for a low toxin vetch

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Max at Strathalbyn with a vetch plot (2012)

Some time ago Dirk Enneking asked me to write a summary of the late Max Tate's progress in developing a low toxin vetch. Just before his death, Max handed the vetch project to Professor Iain Searle at The University of Adelaide. For those who are interested, Vy Nguyen has recently published a paper outlining the procedure this group is intending to use to achieve a low toxin vetch (Nguyen, et al. 2020, Frontiers in Plant Science 11, 818.) It is not possible to summarise Max's work without thanking the people who helped him and trying to acknowledge those who made a major contribution to the low toxin vetch project.

Max was overseas on sabbatical when Dirk informed him about the large quantities of split vetch (*Vicia sativa* L. cv Blanchefleur) being sent from Australia at prices that suggested the vetch was not being used as stock feed. From Max's and Dirk's research it became apparent that vetch (*Vicia sativa* L.) contained several anti-nutritional factors or toxins, mainly vicine, convicine and γ-glutamyl-β-cyanoalanine.. Vicianine, a cyanogenic glycoside associated with vetch is absent from Blanchefleur. An additional problem with vetch (first reported when the vetch-lentil substitution was investigated) is that vetch is very slow to cook when compared with lentils. Lentils cook in about 15 minutes compared with more than 2 hours for vetch.

It should be noted that *Vicia sativa* L. should not be confused with other types of vetch. Purple vetch (e.g. *V. benghalensis* cv. Popany), woolly pod vetch (e.g. *V. villosa* ssp. *dasycarpa* cv. Namoi) and bitter vetch (*V. ervilia*) all contain canavanine, a non-protein amino-acid, which interferes with protein metabolism thereby leading to death by starvation.

Vicine and convicine are also found in faba beans (*Vicia faba* L.) and are the cause of favism in some people from the Mediterranean region with a certain genetic predisposition. Similarly, anyone feeding Merino sheep on faba bean stubbles may have noticed a few sheep die from haemolytic anaemia. These sheep were susceptible to high levels vicine and convicine in their diet.

The toxin that worried Max the most was γ-glutamyl-β-cyanoalanine. Charlotte Ressler had pointed out its toxicity to poultry in 1969. Max and Dirk searched the literature for documentation of the effects of regular consumption of vetch by people and found it always ended badly. Feeding trials in pigs and poultry by Jane Rathjen confirmed Max's suspicions that vetch should not be fed to people as part of their staple diet. It was probably not a good idea to feed it to Sri Lankan school children as part of their lunch menu, but this was one of the destinations of red split vetch being exported from Australia.

Max's attempts to warn the farming community about red split vetch being exported for human consumption, with vetch-lentil substitution being rife, generally fell on deaf ears. Even though Max had his supporters, Max's decision to publish his concerns in Nature proved highly controversial, alienating both farmers and scientific researchers. Fellow researchers were not willing to support him because they were worried about their careers. Rade Matic (SARDI vetch breeder) and Max came to loggerheads. Later, with the ban on exporting red split vetch, the lentil industry blamed Max for making it harder to export lentils because of greater regulations and increased inspections.

Max desperately wanted to give something back to the farming community and so for more than 20 years Max contributed his time and money trying to breed a low toxin vetch. His objective was to reduce the toxin level enough for human consumption. Many people helped Max with his quest.

Dirk was not only the person to get Max involved in vetch. He has an encyclopaedic knowledge regarding *Vicia* species and is a passionate supporter of Max. Dirk also developed an innovative bioassay for low toxin vetch using garden snails (Figure 1). Snails prefer the low toxin vetch.

Figure 1. Snail bioassay where snails prefer the low toxin vetch over the high toxin varieties (Dirk Enneking)

Max's first PhD student to work on the low toxin vetch was Ian Delaere. Ian developed methods to quantify the amount of γ-glutamyl-β-cyanoalanine in vetch and to do this he needed to isolate the compound from vetch seeds. Diffuse-reflectance mid-Infrared spectroscopy became the method of choice for quantification because it was relatively cheap and could measure the toxin level in individual seeds. Using Ian's methods over 2500 lines from ICARDA (Aleppo, Syria), Australian Temperate Field Crops Collection (Horsham, Victoria) and the Vavilov Institute (St Petersburg, Russia) were analysed but none had low toxin. Some of these lines were mixed and in retrospect it would have been better to analyse pods from individual plants, this was not possible due to quarantine restrictions and the large numbers involved.

Jane Rathjen also did her PhD with Max. Jane showed that the only method to completely detoxify vetch, was by autoclaving for 8h. Jane's feeding trials showed that vetch was toxic to both chickens and pigs. Jane did manage to obtain low toxin lines from Iran (IR28 and IR36) which formed the basis of Max's breeding programme, and she made some initial crosses with these lines.

During this time a series of French students also worked in Max's laboratory on vetch as part of their undergraduate study requirements. Each student made a small but important contribution to the low toxin vetch project. At this time, Lawrence and Mavis Jericho, farmers from Cummins, gave their Jericho White line (a selection from Languedoc) to Max so that he could produce a low toxin vetch with a distinctive colour.

Doza Chowdhury worked with Max for many years crossing the low toxin lines with locally adapted varieties. Much of this was unpaid except for a SAGIT grant. Even after Doza had moved to Narrabri, he returned to help Max with crossing and harvesting. Doza managed to identify another source of low toxin vetch from a Bulgarian line supplied by Rade Matic. Doza was the main person behind Max's Love 2 white seeded variety (Figure 2).

Figure 2. Love 2, the only variety registered by Max used the Jericho White variety for the distinctive white seed coat

The faba bean group under the leadership of Jeff Paull also gave considerable support to Max by providing areas in the screen house and Charlick Experiment Station, Strathalbyn for growing vetch. After Doza died, Shi Yang (from Jeff Paull's team) helped Max with crossing vetch and even made an educational film with Max on how to cross vetch.

Klaus Oldach from SARDI did some sequencing work on vetch nitrilases. Nitrilases are the enzymes that detoxify either γ-glutamyl-β-cyanoalanine or its precursor β-cyanoalanine. Max's early work centred on lines with high nitrolase activity However, as Max never quite achieved the levels he wanted, Max turned his attention to synthesis genes. Two honours students, Adriel Carlos da Silva and Yingu Huang sequenced two different cyanoalanine-synthase genes in vetch.

Max's vetch breeding programme suffered from a few constraints besides a lack of funding. Max only had a few low toxin lines to work with and none of these were zero toxin. Another problem was a huge seasonal variation, with it accounting for approximately 50% of total variation (Figure 3). To minimise, this Max developed a different selection method by estimating total seed-toxin for the whole pod from the toxin content of the first and last seeds and this value normalised in terms of the mass of the empty pod to give the total seed toxin per pod (Figure 3).

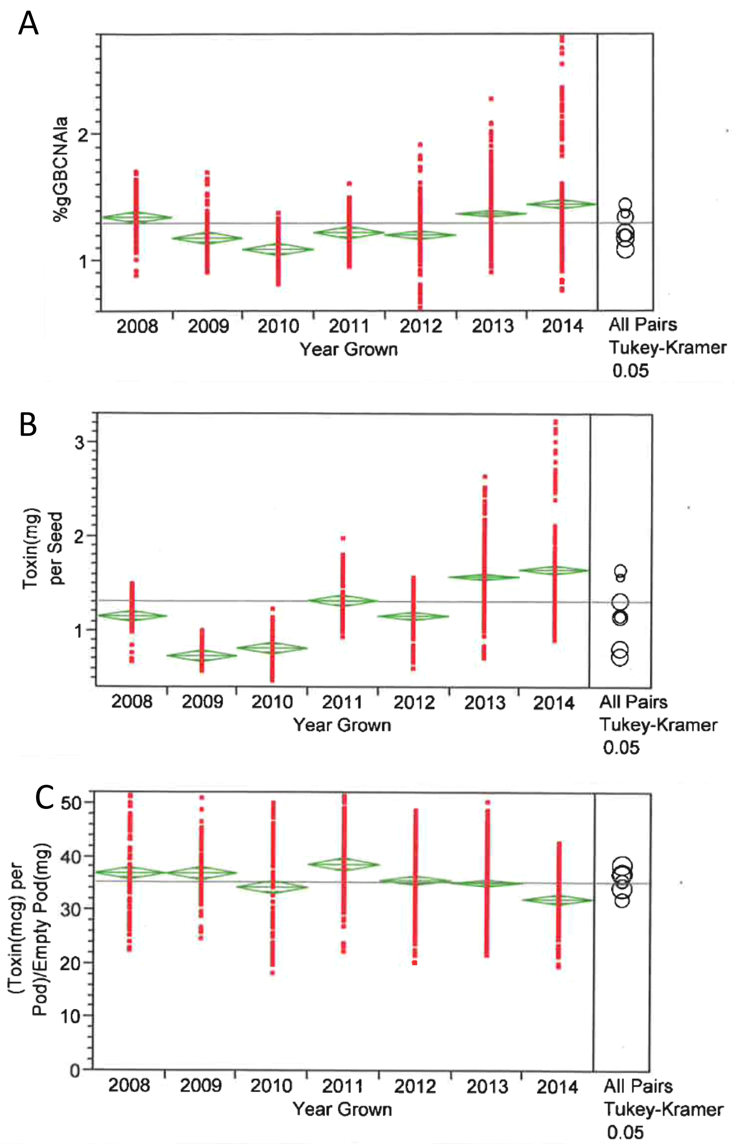
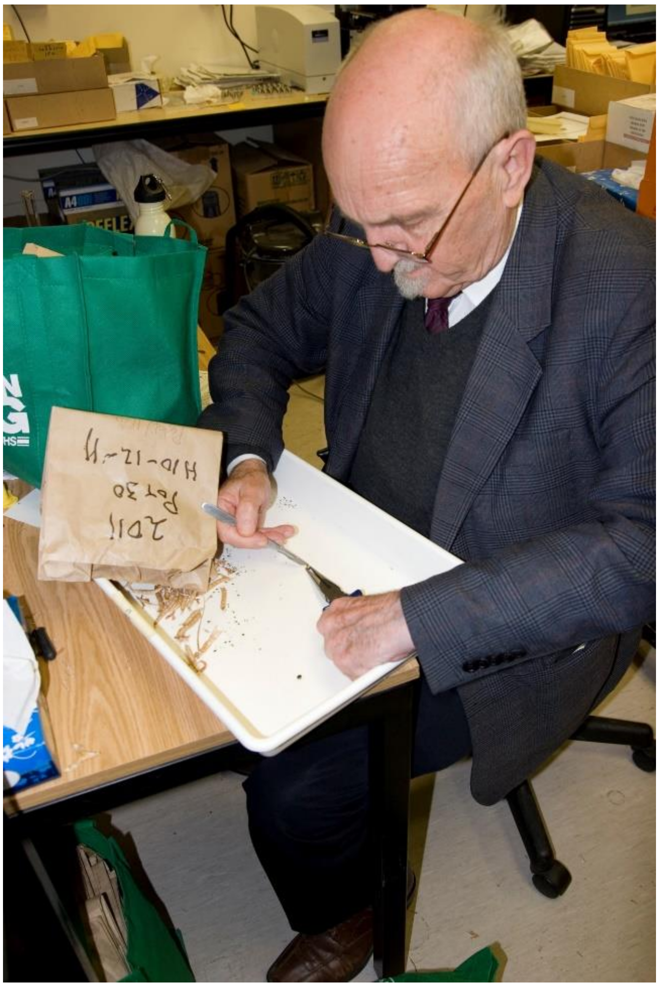


Figure 3. A & B Languedoc toxin levels for years 2008 to 2014 showing high seasonal variation and C Max's method to reduce the effect of season to make it easier to select low toxin varieties. Note: diamonds represent 95% confidence intervals for each mean with centres indicating the mean.

At the time of his death, Max was unable to produce the low toxin vetch he wanted in spite of his best efforts and those that helped him. In locally adapted varieties toxin levels were reduced from approximately 1.5% to 0.4% in the shade-house and 0.7% in the field, which were not quite low enough to feed pigs and poultry. We will only know how close Max was to achieving his goal once an ultra-low or zero toxin has been bred.

However, data obtained from my final experiment with Max suggested there may be enough nitrilase activity in the harvested grain to reduce the remaining toxin levels using a post-harvest treatment that doesn't work in the high toxin varieties. The question is whether there a market for such a low toxin vetch product.

Thank you to everyone who helped Max in his quest for a low toxin vetch.



Max hard at work in his office (2012)