Strategies and tactics to extend whole-farm water-use efficiency - sow on-time or early!

James Hunt, John Kirkegaard, Julianne Lilley, Susie Sprague, Tony Swan, Brad Rheinheimer

CSIRO Sustainable Agriculture Flagship

Dannielle McMillan, Alison Frischke

BCG

Paul Breust, Tony Pratt

FarmLink Research

Key Messages

- Maximise wheat WUE by ensuring as much crop flowers during the optimal period as possible – sow on time or early!
- Early sown, slow maturing varieties (winter and spring) yield as well as or better than faster maturing varieties sown later
- Including an early sown variety in a cropping program can greatly increase whole-farm yield

Key Words

early sowing, slow maturing wheat, winter wheat, time of sowing, frost

Introduction

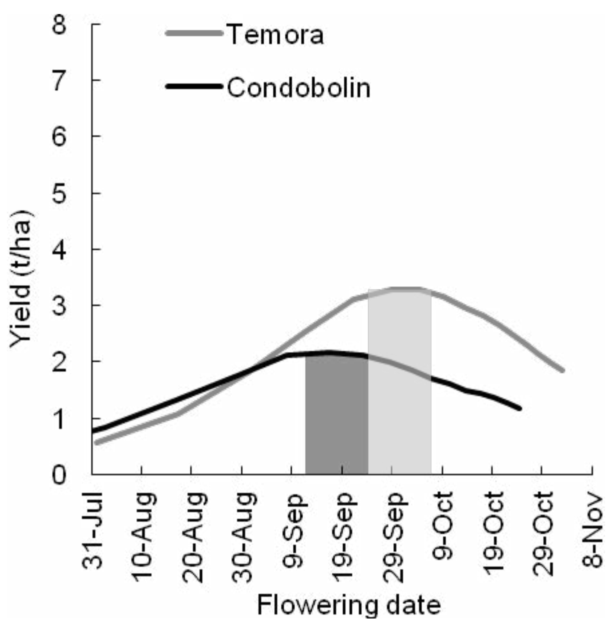
The dry autumn and frosty spring of 2013 continues the pattern of the last 17 years, and is likely to continue into the future (Cai et al. 2012). Getting wheat to flower during the optimal period in a given environment is a huge driver of yield and water-use efficiency, particularly with the recent pattern of late frosts and early heat - and dry autumns make achieving this very difficult. The majority of current wheat varieties need to be sown in the first half of May in order to flower during the optimal period for yield in most environments, which unfortunately coincides with the period of recent rainfall decline.

Growers wishing to maximise farm water-use efficiency need to adopt strategies that will allow them to get as much of their wheat crop as possible flowering during the optimal period in their environment. This means having the varieties, rotations, equipment and level of organisation required to take advantage of any sowing opportunity that arises from late summer onward. This article reports results from several experiments conducted across southern Australia and farmer experience investigating the potential for earlier sowing to increase wheat yields in the face of autumn rainfall decline.

Optimal Flowering Periods

Every production environment has an optimal period in which wheat crops need to flower in order for yield and water-use efficiency to be maximised (Figure 1). This period is defined by an optimal balance between temperature, radiation and water availability, and also decreasing frost risk and increasing heat risk. Optimal flowering periods vary for different locations e.g. the optimal flowering period for western NSW is early to mid September, whilst in the tablelands around Canberra it is the start of November. Growers and advisors should have a firm understanding of the optimal flowering period in their environment, and how to achieve it from different sowing dates with different varieties.

Figure 1. The relationship between flowering time and yield at Temora and Condobolin – optimal flowering periods are highlighted by light and dark grey boxes. Curves are derived from APSIM from 120 years of climate and with a yield reduction for frost and extreme heat events. Optimal flowering periods are mid-September at Condobolin, and late September-early October at Temora.



The key challenge for growers wanting to maximise whole-farm yield and WUE is to have as much of their wheat crop as possible flowering during the optimal period. This has become increasingly difficult for three reasons;

1. Autumn rainfall has declined significantly in the last 17 years, most likely as a direct consequence of anthropogenic climate change.
2. Recently released varieties for most environments have a very narrow range of maturities and unstable flowering times and only flower during the optimal period if sown between late April and late May.
3. Farm sizes and cropping programs are getting bigger.

For these reasons, growers increasingly need to be able to take advantage of whatever sowing opportunities they can get, and there are three strategies that can be employed in order to ensure as much wheat crop as possible flowers during the optimal period.

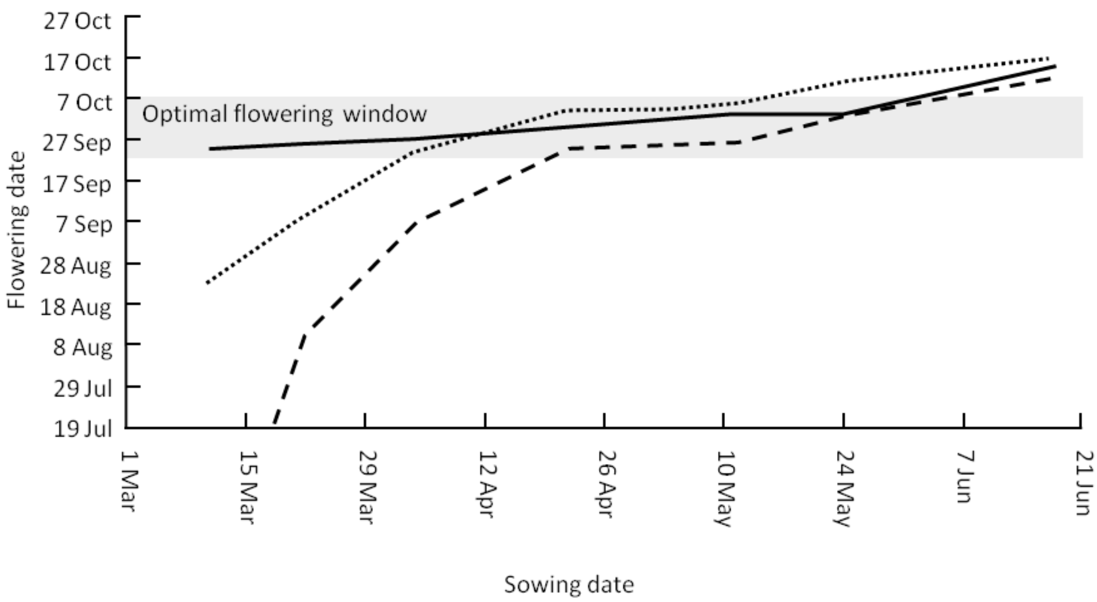
1. Sow winter wheats from late February through to April
2. Sow slower maturing spring wheats from mid-April to early May
3. Sow mid-fast wheats from late-April onward - including dry sowing if the break has not arrived by this time.

Currently most growers are comfortable with the third strategy, and this has been the principal adaption to the drying autumns. However, there is great potential for the first two strategies to complement May sowing and further increase farm yield.

Achieving Optimal Flowering Periods - Experiments 2013

February-March rainfall has not declined over the past 17 years, and in some areas it has increased (Hunt and Kirkegaard 2011). This rain can be used in lieu of the traditional autumn break to establish crops, but winter wheats are required to achieve this. Winter wheats have a vernalisation or cold requirement which means they will not develop beyond tillering until they have been exposed to a certain duration of low temperatures (~4-18 C). This gives them a very stable flowering date from a broad range of sowing dates (Figure 2). They can even be sown in summer, and not flower until the optimal flowering period in spring. They are often only thought of as ‘dual purpose’ (grain and graze) varieties, and have been undervalued as grain-only varieties, particularly in drier areas of the country. Unfortunately, Australian breeding programs stopped selecting for milling quality winter wheats early last decade. There are very few cultivars available, particularly for medium-low rainfall zones with alkaline soils. Commercial breeding companies have now resumed selection for winter wheats, and it is likely that they will play a greater role in our future farming systems as modern, adapted varieties are released.

Figure 2. Flowering date of three wheat cultivars from sowings between March and June at Wagga Wagga in 2006 (GRDC, 2011). EGA Wedgetail (-) is a winter wheat with a moderate photoperiod requirement, EGA Eaglehawk (····) is a very slow maturing spring wheat with a strong photoperiod requirement and Janz (– –) is a mid-fast spring wheat with a minor photoperiod requirement (adapted from GRDC Southern Region Time of Sowing Fact Sheet using data from Peter Martin, NSW DPI).



Sowing winter wheats on summer rain

The Curyo district north of Birchip received 50 mm of rain in mid-February 2013. As part of their Grain and Graze II project, BCG took the initiative and planted an experiment (sown 26 February, 2013) which consisted of a range of winter wheat varieties from various sources planted on a chick-pea stubble. The farmer's paddock (Kord wheat sown 18 May) provided the experimental control.

The winter lines emerged successfully and survived one of the hottest and driest autumns on record. When rains finally came at the end of May, they regenerated rapidly and were able to flower during the optimal period for that environment (Table 1). Yields of the highest yielding lines (Table 2) were equivalent to that of the farmer's paddock sown in May (3.6 t/ha), despite most of the winter varieties having been released over a decade ago, and having no adaptation to the Mallee environment (CCN, salt or boron resistance).

Table 1. Growth stage of different varieties assessed on 12 September 2013. Mid-September is the optimal anthesis (flowering) period for wheat in the southern Mallee.

Variety	Ungrazed		Grazed	
	Zadoks code	Growth stage	Zadoks code	Growth stage
YW443	46	Booting	39	Flag leaf emerged
Whistler	63	Early anthesis	51	Early heading
Wylah	61	Early anthesis	64	Mid anthesis
Wedgetail	66	Mid anthesis	61	Early anthesis
Rosella	60	Early anthesis	51	Early heading
Revenue	39	Flag leaf emerged	33	Three nodes on main stem
CSIROW8A	53	Early heading	51	Early heading
CSIROW7A	67	Late anthesis	63	Early anthesis

Table 2. Ungrazed grain yield and quality of the winter wheat varieties in the BCG experiment planted at Curyo in 2013

Variety	Grain yield (t/ha)	Protein (%)	Screenings (%)	Test weight (kg/hl)
CSIROW7A	2.7	13.7	1.9	80
CSIROW8A	2.4	13.3	4.3	80
Revenue	3.4	11.5	4.6	76
Rosella	3.3	12.2	2.7	81
Wedgetail	2.8	12.4	2.5	77
Whistler	3.0	11.8	4.3	79
Wylah	2.8	13.1	2.6	76
YW443	1.7	15.4	3.7	74
P-value	<0.001	<0.001	<0.001	<0.001
LSD (P=0.05)	0.3	0.9	1.2	3
CV%	6.5	4.6	24.1	2.3

Sowing opportunities - take them as they arise

In regions such as southern NSW, which is lucky to have adapted winter wheats and slow maturing spring wheats (Eaglehawk, Bolac, Lancer) available, it has been repeatedly shown that there is a clear yield benefit from planting slower maturing varieties early (see GRDC update articles 2013). This was again the case in 2013, as demonstrated by a CSIRO and Kalyx trial comparing the grazing potential and grain recovery of winter and spring wheats sown at different times and with different grazing regimes. The experiment was located at Iandra north of Young on the SW slopes of southern NSW (571 mm median annual rainfall with equi-seasonal distribution). The site received 81 mm of rain from 24 February to 1 March 2013, which was followed by 14 mm on 23 March which made for ideal sowing conditions for a winter wheat (Wedgetail) on 26 March. Another 13 mm fell on 29 March, and the crop emerged well and grew rapidly.

Like most of SE Australia, April was very dry, and no further significant rain fell until mid May. Bolac was planted in its ideal window on 23 April, but into marginal seed-bed moisture, and only 30% of the crop emerged at this time. Gregory was sown dry on 8 May, and it and the remaining Bolac only emerged following 8 mm rain on 14 May. Winter was wet, but spring was dry, frosty and hot and the site received 280 mm for the growing season. The site was located on a hill and so largely avoided the black frost of 18 October which devastated crops in the region.

The yields very clearly show the benefit of using slower maturing wheats (winter and slow maturing spring) to take advantage of any establishment opportunity that arises early in the season (Table 3). Wedgetail and Bolac both had a 0.6-0.9 t/ha yield advantage over main season Gregory.

Needless to say, the Wedgetail also provided significantly more forage (2.6 t/ha) than both the spring wheats (0.8 t/ha for Bolac and 0.4 for Gregory), however grazing reduced yield. This (and the BCG data above) debunks a common misconception that winter wheats are only dual purpose varieties and have to be grazed in order to manage their canopy and achieve good yields. Winter wheats can be highly flexible grain-only varieties in their own right, and a very important tool for managing climate variability.

Table 3. Crop yields from four treatments at the CSIRO and Kalyx experiment at Iandra, NSW comparing grazing potential and grain recovery of winter and spring wheats sown at different times and with different grazing regimes.

Variety and Sowing Date	Yield (t/ha)	Standard Error
Wedgetail - sown 26 March 2013		
Uncut	4.7	0.1
Z30 hard defoliation	4.4	0.2
Bolac - sown 23 April (30% emergence, remainder emerged following rain mid-May)		
Uncut	5.0	0.2
Z30 hard defoliation	4.9	0.1
Gregory - sown 8 May 2013		
Uncut	4.1	0.2
Z30 hard defoliation	4.0	0.1

Farmer Experience in 2013

The early sowing message has been rapidly adopted by farmers and advisors in southern NSW where suitable varieties are available, and the following case studies describe some successes and pitfalls of the approach.

Charlie and Lou Clemson, Ardlethan

The Clemson's farm south of Ardlethan received ~50 mm in a highly localised storm at the end of March. Charlie was understandably wary of the recent run of dry autumns, and not knowing when the next sowing opportunity was coming, decided to start planting wheat. He had Bolac seed from 2012, clean canola stubbles on their home block, and started planting on 4 April and finished by 11 April. Paddocks sown on 4 April emerged very quickly, those sown by 7 April were slower as things dried out, which probably turned out to be a good thing.

The start of April is a critical time for slow maturing spring wheats, as it is then that days just become short enough for the photoperiod sensitivity of slow maturing spring wheats to hold back their development (see how Eaglehawk and Janz development becomes slower at the start of April in Figure 2). That is why winter wheats are required for sowing before ~10 April, as their vernalisation requirement stops them from developing when days are long. The Bolac sown on 4 April was probably exposed to enough day length to speed its development, and it had started flowering on 5 August – a good month before the optimal period in that environment. It suffered 40% frost damage, probably from a frost on 16 August (-1.3°C recorded at West Wyalong AWS), but still averaged ~2.5 t/ha of H2 (Table 4). The Bolac sown 7 April flowered quite a bit later and only suffered ~10% damage, and averaged ~4.2 t/ha of H2. Average Bolac yield across the home farm was 3.7 t/ha.

On another two blocks further west, Bolac sown 12-18 April averaged 3-3.3 t/ha (26% of wheat crop) whilst main season varieties (74% of wheat crop) averaged 2.0 t/ha. Across all three farms, Bolac sown 4 to 18 April averaged 3.5 t/ha whilst main season wheats (Gregory, Kord) sown 1 May to 7 June averaged 2.1 t/ha. This reflected the results of the CSIRO, FarmLink and NSW DPI experiments showing the yield advantages of slow maturing wheats sown early.

Charlie and Lou were generally pretty pleased with the result, and next year will trial some different slow maturing spring wheats and winter wheats on their farm, and depending on results look to use winter wheat if they get a sowing opportunity in early April again.

Table 4. Hand harvest yields, frost induced sterility and machine harvest paddock averages for Clemson's Bolac sown in early April. Numbers in brackets are standard error of the mean – if standard errors overlap then means are unlikely to be significantly different.

Sowing Date	Hand harvest yield (t/ha)	Frost induced sterility (%)	Paddock average yield (t/ha)
4 April	3.0 (0.4)	44 (10)	2.6
7 April	4.2 (0.2)	10 (2)	4.2
8 April	4.9 (0.5)	9 (3)	4.2

Figure 3. Lou and Charlie Clemson inspecting one of their early sown Bolac paddocks just prior to starting harvest on 24 October.

Heidi and David Gooden, Osborne

The Osborne district got a sowing opportunity at the start of April, and Heidi and David replicated over hundreds of hectares on their farm the small-plot experiments that CSIRO, FarmLink and NSW DPI had done in the GRDC water-use efficiency project which demonstrated the yield advantages of early sowing (see GRDC advisor update papers from 2013 for results of these experiments). The strategy fitted well with their sowing operation – they planted Wedgetail and Eaglehawk from 12 April, then canola before switching to Bolac and Lancer around Anzac day and finishing with Gregory and Lincoln in early May. The winter at Osborne was exceptionally favourable, and all crops looked sensational… until the Black Frost of 18 October! Frost damage and yields were largely determined by elevation and position in the landscape. Hand-cuts taken on hills show that the findings from the small plot trials held true – early sown, slow maturing wheats yielded more (Table 5). However, across whole paddocks frost was huge driver of yield (Figures 4 & 5), and average paddock yields were not that different to each other and Gregory sown later achieved better quality (Table 5).

Whilst Gregory on the hill appears to have sustained more frost damage, the absolute number of first florets which were either sterile or contained damaged grain (5 per head) was similar to Eaglehawk on the hill (3 per head), but Eaglehawk had 23 spikelets per head whilst Gregory had only 17. So whilst the percentage damage was higher in Gregory, in absolute terms (t/ha) the damage in both varieties was about the same.

The Gooden's are a little trepidatious about trying early sowing with slow maturing varieties again – they are unsure if the high biomass of early sown crops is appropriate for there environment and farming system, and in a frosty year the early sown crops showed no benefit over mid varieties sown later.

Table 5. Yield and total frost damage (frost-induced sterility and damaged grains) from hand-harvests (4 x 0.9 m quadrats from each treatment), and paddock averages from header yield monitor at Gooden's farm in 2013. Numbers in brackets are standard error of the mean – if standard errors overlap then means are unlikely to be significantly different.

Variety & Sowing Date	Grain yield (t/ha)		Total frost damage (%)		Paddock average yield and quality (t/ha
	Hill	Flat	Hill	Flat	
Eaglehawk 12 April	6.2 (0.1)	1.7 (0.2)	16 (3)	92 (4)	2.9 (HPS1)
Wedgetail 12 April	5.5 (0.3)	-	9 (2)	-	3.5 (AUH2)
Bolac 23 April	5.7 (0.2)	3.2 (0.5)	1 (1)	61 (18)	2.9 (FED1)
Gregory 5 May	4.2 (0.2)	-	33 (3)	-	3.5 (APW1)

Figure 4. Relationship between elevation and yield for Bolac sown 23 April 2013from Gooden's header yield monitor. Each data point on the graph is an average for each 1 m of elevation and represents thousands of datapoints. Elevation explains 94% of the variation in yield, and yield increased by 0.21 t/ha for every 1 m of elevation.

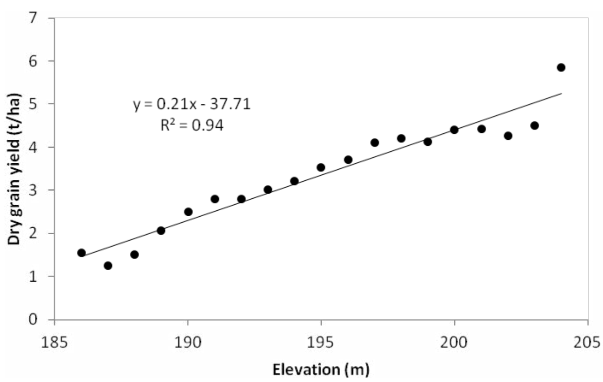


Figure 5. The relationship between frost damage (%) and grain yield from hand harvests at Gooden's farm in 2013.

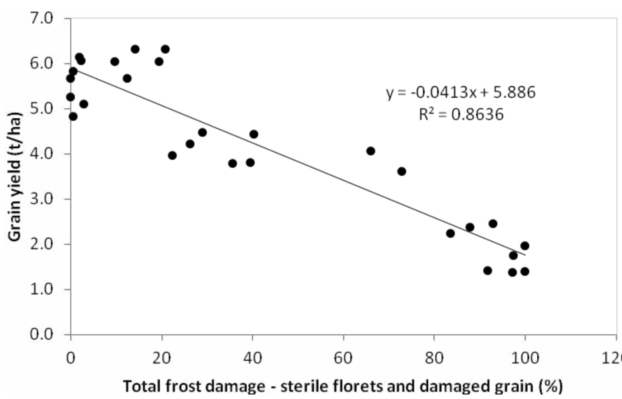


Figure 6. Heidi, David and Adam Gooden stand in their crop of Eaglehawk sown 12 April 2013. This photo was taken at the end of August, the crop ended up being ~1.2 m tall!

A WORD ON FROST

The black frost of 18 October 2013 was financially and psychologically devastating to growers across southern NSW and Victoria who were affected. However, one learning from the catastrophe was that delaying sowing (or flowering) is not an effective way of managing risk of late-season frosts. This was starkly illustrated by a grower (who shall remain nameless!) on the south west slopes of NSW who mixed up his seed silos and planted Spitfire on 22 April and Bolac in May. This generated a very broad range of flowering dates from ‘too early’ to ‘too late’, but all crops were equally affected.

Further evidence of this was provided by a CSIRO experiment in a frost-prone site south of Temora. The experiment was dry-sown on 23 April, but only emerged following rain on 8 May. It included varieties with a broad range of maturities, and flowering extended for a fortnight from ‘too early’ until ‘too late’. Air temperature fell to -3.6°C on the morning of 18 October, and despite all varieties suffering ~60% frost damage, yield still very clearly declined with flowering date (Figure 7). Varieties which flowered on time (or early!) yielded the most.

To have had crops flower after the 18 October frost would have required delaying sowing with main season wheats well into July, which in the majority of years is guaranteed to result in poor yields. Delaying sowing past the optimal date for a given variety is not an effective way of managing frost risk, and historically has probably cost more yield than frost itself.

There are more successful ways to manage frost risk than delaying sowing. Another result from a different experiment at the same Temora site (funded through the GRDC stubble initiative and run in conjunction with FarmLink Research) comparing grazed, burnt and retained stubbles clearly demonstrated the insulating effect of stubble on the soil surface during frost events, and resultant increase in frost damage (Table 6). A similar yield result was observed in 2012, but whilst stubble retained treatments appeared visually to have more frost damage, frost scores showed no significant difference. These trials show the potential of burning stubbles in frost prone sites to reduce the risk of damage.

Figure 7. Relationship between flowering time and yield at a CSIRO experiment at Temora in 2013. The optimal flowering period in this environment is the first week of October

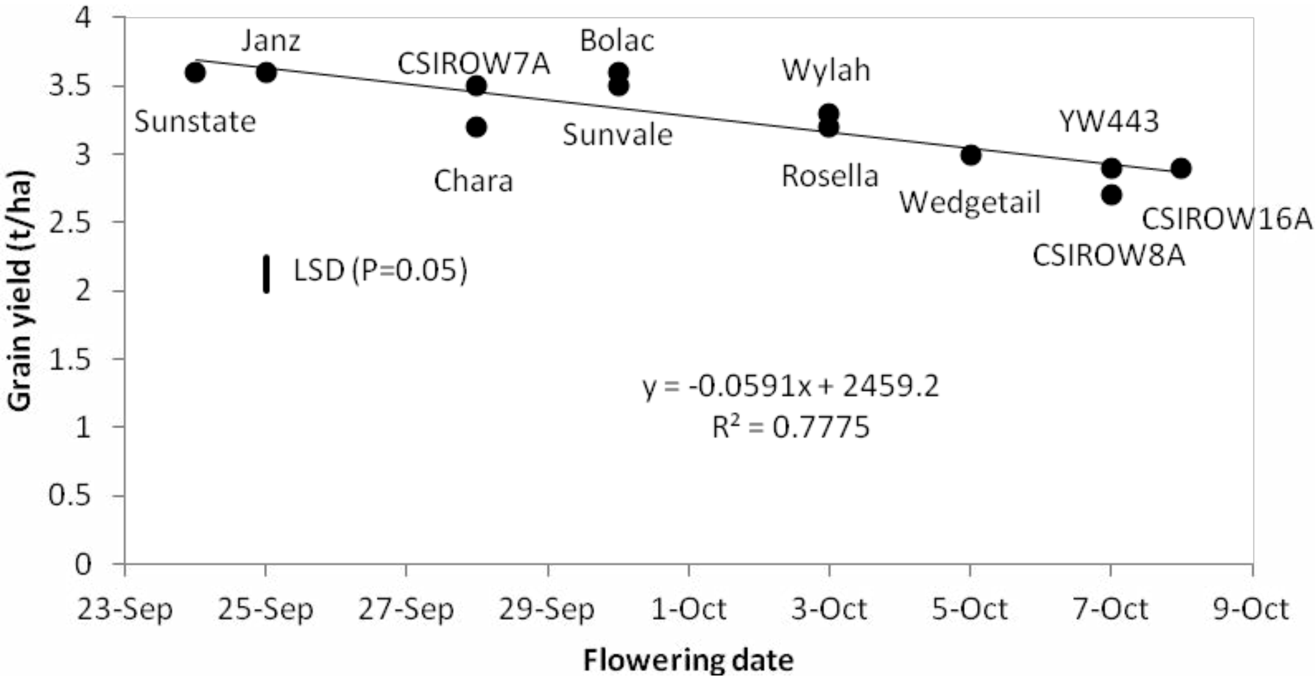


Table 6. Grain yield and frost damage for different stubble treatments applied prior to sowing at the FarmLink and CSIRO stubble initiative site at Temora.						
Treatment	**2013 wheat yield (t/ha)**		**2013 canola yield (t/ha)**		**2012 wheat yield (t/ha)**	
	Burn 30% frost damage	**Retain 59% frost damage**	**Burn 43% frost damage**	**Retain 59% frost damage**	**Burn 10% frost damage**	**Retain 10% frost damage**
Nil Graze	3.3	2.2	1.0	0.7	5.0	4.4
Stubble Graze	3.6	3.0	1.1	0.9	4.8	4.8
P value	<0.001		0.014		0.003	
LSD (P<0.05)	0.2		0.1		0.3	

Another observation from the 18 October frost and previous events was the strong effect of elevation (Figure 3). This means that frost is able to be managed spatially, and on the SW slopes, farms zoned according to how frost-prone different regions are were able to avoid the worst of the damage. Frost sensitive crops are not planted in low lying or frost prone paddocks, and only pasture, hay crops, dual-purpose wheat or barley are grown in these areas.
The last obvious way to manage frost risk is through enterprise diversity. Farms in frost-prone areas should maintain enterprises not exposed to frost risk. These could be off-farm investments, or on farm such as livestock or hay.

PUTTING IT INTO PRACTICE

Growers wishing to sow early in 2014 need to get themselves in a position to take advantage of early sowing opportunities should they arise. Early-sown wheat needs weed and disease free paddocks – a double break (e.g. pulse/legume pasture/hay crop followed by a canola crop) is an ideal set-up for early sown wheat, particularly in higher rainfall areas.

Growers also need to have a good idea of what their optimal flowering period is, and how to achieve it from different sowing dates with a range of varieties most suited to their environment. If growers keep 2-3 varieties (one winter and one or two spring wheats), they are able take advantage of any sowing opportunity that may arise over a three month period (Table 7). It does require growers to be tactical in how much of each variety they grow in a given year, but the potential yield benefits well outweigh the logistical hassles. In southern NSW, growers only need to keep two varieties (Wedgetail and either Suntop or Gregory) in order to give themselves a very broad sowing window.

Table 7. Wheat maturity groups, sowing windows to achieve optimal flowering windows and examples of best-bet varieties within groups for southern NSW.

Winter wheats	Slow maturing spring wheat	Mid maturing spring wheat	Fast maturing spring wheat
Late February - Late April	**Mid-April – early May**	**Late-April – mid May**	**Mid May onward**
Wedgetail, Wylah, Whistler	Bolac, Lancer, Eaglehawk	Suntop, Gregory (both these varieties are competitive with fast spring wheats when sown later in May)	Spitfire, Wallup, Emu Rock, Lincoln, Livingston, Corack

Early sown crops do require different management to later sown crops. In higher rainfall regions Septoria tritici is a very serious pathogen of early sown crops, and it is recommended that flutriafol in-furrow and earlier foliar sprays are used when sowing early. Barley yellow dwarf virus can be a threat in all environments, and it is recommended that seed be treated with imidicloprid, or crops closely monitored for aphid infestation and sprayed accordingly. Wheat streak mosaic virus is a very serious threat in the higher rainfall zones of SNSW, and there is no chemical control for this disease or its insect vector. The slow-maturing spring variety Forrest has tolerance to the virus, but is really only suited to mid-April sowing, at which time the risk of the virus affecting crops is greatly reduced. Forrest also appears to have a 'glass jaw' – it performs well in favourable seasons, but is not competitive with other slow maturing varieties in dry springs.

If planning to graze crops, higher seeding rates and up-front N will maximise early dry matter production. If crops are not to be grazed, then N fertiliser should be deferred until after Z30 to avoid excessive early growth, and if initial soil N is high sowing rates should be reduced (~50-80 plants/m^2). Yield effects of grazing are variable – sometimes positive and sometimes negative, but the effect size is rarely more than 0.5 t/ha if grazed in the safe window (prior to Z30). It is certainly not necessary to graze early sown crops to maximise grain production, but they can offer significant amounts of forage at a time when feed can be scarce.

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Contact details

James Hunt
GPO Box 1600 Canberra ACT 2601
02 6246 5066
E: james.hunt@csiro.au