Can we refine winter crop planting dates further?

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AT A GLANCE…

- Of all the agronomic 'levers' available to growers planting date still offers one of the greatest abilities to increase yield potential.
- There are drastic changes in frost risk with only small changes in elevation (20–50 m), which presents significant opportunity to push planting dates forward without necessarily increasing frost risk.
- Lower points in the landscape/paddock have more frost events with greater duration compared to higher elevations. Therefore there is slower accumulation of growing degree days at these lower points in the landscape, consequently slowing the development of the crop.
- There is little variation in maximum temperature across elevations. Therefore in lower parts of the landscape, where the frost risk persists longer into the season, the heat stress will start at the same time as higher elevations. This narrows the window for optimum conditions for flowering crops.

MAJOR management 'levers' that can be manipulated to achieve yield potentials include planting date, planting configuration (row spacing and seeding rate), variety choice, disease and weed control, nitrogen, phosphorus and other nutrition. Of these levers planting date can have the greatest impact achieving yield potential and is one of the few management tools that can be changed with negligible additional costs to the grower.

The degree that planting date will determine grain yield potential will be greatest in dry and hot springs and least in wet and mild springs.

Planting date determines when the plant will reach anthesis. Pushing sowing dates earlier increases yield potential through increased biomass accumulation and by extending the length of grain filling period under cooler spring temperatures. But earlier planting dates also increase the risk of incurring a frost during flowering.

Sowing later to minimise frost risk then pushes crops to grain fill under hotter spring conditions leading to lower yield potentials. Key questions include:

- Are we losing yield with current grower (traditional) sowing dates? and,
- What other tools are available to manage our sowing dates as early as possible without taking on board unacceptable frost risk?

Growers generally take a conservative approach to planting date as the fear of frost damage influences their decisions to a greater extent than the often intangible yield loss from heat stress during grain fill.

Currently growers and agronomists rely heavily on previous experience, local weather station data, sowing guides and predictive models such as Climate or APSIM to determine planting dates. The problem for growers and agronomists is that typically the local weather stations are located some distance from paddocks or farms which then requires a degree of interpolation (estimation).

Models are also based on these weather stations as well, which means growers can only use results as a guide. In relatively flat areas like Walgett in northern NSW, the individual farm variation from the weather station may be very small. For other locations like the Liverpool Plains, where there is a large variation in elevations, there is likely to be large differences across farms in their temperature regime as compared to the Gunnedah or Quirindi weather stations.

Our research aims to reduce some of the interpolation required by growers and agronomists by looking at the impact that elevation has on frost risk and subsequently planting dates across different elevations.

But the project hasn't taken into account other factors that will influence frost risk or cold air drainage such as aspect, drainage, tree lines and the point in the landscape.

The data produced from this project could be used in models to enable them to better predict frost risk and planting dates across the landscape rather than localised near a weather station.

What has been done?

In 2014, 2015 and 2016 two paddocks containing significant elevation differences (20–45 metres) were selected, one near Gurley and one on the Liverpool Plains. In each paddock a site was selected at the top of the slope and a site was selected at the bottom of the slope. Tiny Tags were installed along with rain gauges at both sites in each paddock to record temperature (every 15 minutes) and rainfall.

Six wheat varieties including LPB Dart, LPB Spitfire, Suntop, LPB Lancer, EGA Gregory and EGA Eaglehawk were planted on three planting dates (approximately last week of April, mid May and early June for all trials) at both sites.

Regular phenology measurements were taken to ascertain development difference both between varieties but also between top and bottom slopes.

A summary of the site planting dates and elevation differences is given in Table 1.

TABLE 1: Details of planting dates and elevation differences at each site between 2014 and 2016

	Premer 2014	Gurley 2014	Spring Ridge 2015	Gurley 2015	Premer 2016	Gurley 2016
Planting dates	30th April 20th May 13th June	26th April 16th May 11th June	30th April 19th May 11th June	26th April 15th May 8th June	29th April 18th May 13th June	30th April 17th May 10th June
Elevation difference	401–377 (24 m)	271–302 (32 m)	354–309 (45 m)	306–263 (43 m)	384–404 (20 m)	309–274 (35 m)

Planting date is one of our most effective management levers.

What we found

Estimations of starting plant available water (PAW) indicated that although profiles were similar between top and bottom slope at all sites the bottom slope generally had slightly higher starting PAW between two and 20 mm more than the top of the slope. In 2015 and 2016 the starting PAW, was approximately 70 to 90 per cent full at the Liverpool Plains and Gurley sites, but in 2014 starting PAW was closer to 50 per cent full at both locations (Table 2). Similar to starting PAW the measured available soil N values were generally slightly higher at the bottom slope sites compared to the top of slope sites containing an additional 2–17 kg N per hectare available at the start of the season (Table 2).

The elevation differences at both sites resulted in significant variation in temperature over the season. Average minimum temperatures across all three years were 2.4 and 2.9°C lower at the bottom slope compared to the top slope at Liverpool Plains and Gurley, respectively, whereas average maximum temperatures were similar for both top and bottom slopes (Table 2).

The differences in average minimum temperatures was exemplified by the differences in frost events (<0°C) with bottom slope at the Liverpool Plains and Gurley. At Spring Ridge and Premer in 2014, 2015 and 2016 the bottom slope experienced an additional 27, 35 and 28 frost events, respectively, compared to the top slope. At Gurley in 2014, 2015 and 2016 the bottom slope experienced an additional 31, 29 and 36 frost events, respectively, compared to the top slope (Table 2). There were not only more frosts at the bottom slope sites but frosts had a greater duration.

On average across years the time that temperatures were at or below 0°C at the top slope was only 36 and 7 per cent of that measured for the bottom slope sites on the Liverpool Plains and at Gurley, respectively (Table 2). Length of the frost event can be a major determining factor of damage.

FIGURE 1: A visual representation of how different maturity was between top and bottom slope at Spring Ridge in 2015

TABLE 3: Average days to flower for LPB Dart, LPB Spitfire, Suntop, EGA Gregory, LPB Lancer and EGA Eaglehawk sown across three planting dates at the top and bottom slope sites at the Liverpool Plains and Gurley

Site	Slope	Late April	Mid May	Early June
Premer 2014	Top	131	126	116
	Bottom	147	138	127
Gurley 2014	Top	94	114	102
	Bottom	106	123	108
Spring Ridge 2015	Top	130	124	117
	Bottom	144	133	124
Gurley 2015	Top	118	109	99
	Bottom	126	116	106
Premer 2016	Top	141	132	121
	Bottom	149	135	126
Gurley 2016	Top	123	119	110
	Bottom	130	126	116

TABLE 2: Soil and temperature differences between top and bottom slope at all sites from 2014 to 2016

Site	Slope	Starting PAW	Soil N (0–1.2 m)	Average min	Average max	Frost events (<0°C)	Cum. hours (<0°C)	Season GDD
Premer 2014	Top	139	110	5.1	24.6	31	97	1963
	Bottom	158	122	2.5	24.8	58	226	1655
Gurley 2014	Top	90	154	7.1	30.7	7	21	2230
	Bottom	108	145	4.4	30.3	38	184	2038
Spring Ridge 2015	Top	185	175	5.4	22.6	16	32	1998
	Bottom	200	192	2.6	23.1	51	243	1752
Gurley 2015	Top	144	104	6.4	25.2	7	17	2186
	Bottom	146	118	2.9	24.8	36	176	2008
Premer 2016	Top	225	125	4.9	22.8	31	132	1869
	Bottom	230	128	3.1	22.9	59	253	1655
Gurley 2016	Top	115	138	6.8	27.9	1	0.45	2138
	Bottom	126	142	4.3	28.0	37	143	1967

This project has highlighted the very large yield and financial benefits possible from early wheat planting at higher, and less frost-prone, parts of the paddock.

On average across the three years the length of frost events at the top slope sites were 3.3 and 2.5 hours for the Liverpool Plains and Gurley, respectively. This is compared to the bottom slope sites on the Liverpool Plains and Gurley where frost events typically lasted for 4.3 and 4.6 hours, respectively.

Growing Degree Days and crop maturity

Lower average minimum temperatures and greater number of frost events both contributed to the slower accumulation of thermal time throughout the season at the bottom slope compared to the top slope.

At both locations the difference in accumulated thermal time (Growing Degree Days – GDD) was in excess of 150 GDD higher at the top slope sites (Table 2).

The variation of minimum temperature and ultimately GDD had significant impact on crop maturity. Despite being planted on the same day at the top and bottom slope sites, the varieties did not reach 50 per cent flowering on the same day. An example of how visual this difference was is shown in Figure 1.

The bottom slope sites were on average across the six varieties 13, 9 and 7 days longer than the top slope to reach flowering on the late April, mid May and early June planting dates, respectively for the Liverpool Plains (Table 3). Similarly, for Gurley the differences in time taken to reach flowering were 9, 8 and 6 days longer at the bottom slope sites than the top slope for the late April, mid May and early June planting dates, respectively (Table 3).

The Liverpool Plains trials were on average 17 days later to reach flowering compared to Gurley trials across the three years.

The Liverpool Plains and Gurley had hot and dry springs in 2014 and 2015 and in these seasons the real benefit of early planting was realised. For example on the Liverpool Plains at the top slope site delaying planting from late April to early June resulted in a 2.24 and 1.04 tonnes per hectare loss in grain yield when averaged across six varieties in 2014 and 2015, respectively (Table 4). Assuming a wheat price of $250 per tonne this is equivalent to $560 and $260 per hectare increase in net returns, respectively.

Despite very favourable spring conditions on the Liverpool Plains in 2016 there was still a 1.34 tonnes per hectare yield penalty for delaying planting dates from late April to early June at the top of the slope. Again assuming a wheat price of $250 per tonne the late April planting date allowed an additional $425 per hectare and $1155 per hectare net return to be realised, compared to the mid May and early June planting dates, respectively at the top of the slope over three years (Table 4).

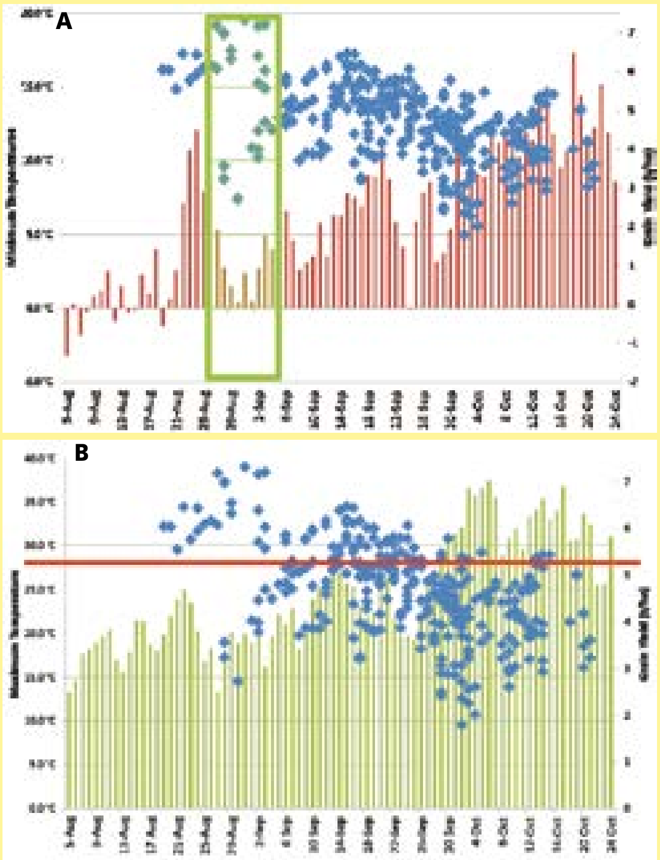
Frost damage did occur at the bottom slope sites on the Liverpool Plains in all three years, particularly in LPB Dart and LPB

TABLE 4: Average grain yield for LPB Dart, LPB Spitfire, Suntop, EGA Gregory, LPB Lancer and EGA Eaglehawk sown across three planting dates at the top and bottom slope sites at the Liverpool Plains and Gurley and restrospective optimum flowering times for highest yield potential					
Site	**Slope**	**Late April**	**Mid May**	**Early June**	**Optimum flowering window**
Premer 2014	**Top**	5.24	4.28	3.00	1st Sep–12th Sep
	Bottom	4.68	4.42	3.16	10th Sep–20th Sep
Gurley 2014	**Top**	—	1.56	1.19	18th Aug–3th Sep
	Bottom	1.26	1.60	1.42	28th Aug–10th Sep
Spring Ridge 2015	**Top**	5.37	4.90	4.33	25th Aug–5th Sep
	Bottom	4.53	5.18	4.60	16th Sep–25th Sep
Gurley 2015	**Top**	5.25	4.56	3.37	11th Aug–24th Aug
	Bottom	4.62	5.01	3.62	24th Aug–9th Sep
Premer 2016	**Top**	7.52	7.25	6.18	8th Sep–28th Sep
	Bottom	7.01	7.34	6.05	20th Sep–10th Oct
Gurley 2016	**Top**	6.32	6.41	6.57	6th Sep–30th Sep
	Bottom	5.98	6.56	6.51	15th Sep–30th Sep

Spitfire. For example LPB Dart in 2015 at Spring Ridge yielded 6.17 and 1.23 tonnes per hectare at the top and bottom slope sites, respectively. The frost damage at the bottom of the slope reduced average grain yield of the six varieties by 1.91 tonnes per hectare across the three years (Table 4). Minimal frost damage incurred on the two later planting dates as grain yields were similar between the top and bottom slope sites for the Liverpool Plains and Gurley in all three years.

Unlike the Liverpool Plains in 2016, there was no yield penalty in delaying planting date from late April until early June at Gurley (Table 4). This is compared to 2015, which had a hot dry spring, where the same delay in planting date resulted in a 1.88 tonnes per hectare reduction in grain yield (Table 4).

FIGURE 2: A) Minimum temperatures (red bars) and grain yield x anthesis date (blue diamonds) for individual plots for top slope at Spring Ridge in 2015. Green box indicates the retrospective optimum flowering date at site. B) Maximum temperatures (green bars) and grain yield x anthesis date (blue diamonds) for individual plots for top slope at Spring Ridge in 2015. Red line indicates 28°C.



What was the optimum flowering time?

The optimum flowering window was retrospectively established by plotting grain yield against flowering date to see what period achieved the maximum grain yields.

At Gurley in 2014 and 2015 the optimum flowering windows were generally 12–14 days from mid to late August for the top of slope site, whereas in 2016 the optimum flowering window was much wider (24 days) and began in early September (Table 4).

The length of the optimum flowering window for the bottom slope site at Gurley was similar to the top slope for the respective years, but it generally started 9–13 days later.

The delayed optimum flowering window for the bottom slope sites was also observed on the Liverpool Plains where it started 10–22 days later than the top of the slope (Table 4).

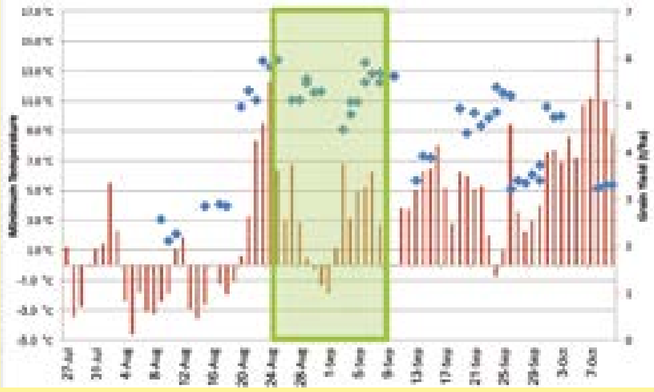
Optimum flowering windows on the Liverpool Plains for the top slope sites generally started around the beginning of September while the optimum flowering window for the bottom of the slope generally started around mid-September (Table 4).

The 2015 season data for Spring Ridge is presented in Figure 2 to demonstrate how the optimum flowering window was determined and how fine the line is between frost damage, particularly at the bottom of the slope.

Further, the 2015 season clearly illustrates the hot dry conditions during grain fill. At the Spring Ridge top slope the highest grain yields were achieved when varieties flowered between August 25 and September 5.

There were no frost events that occurred during this same period, with the last frost event occurring on August 18 (Figure 2A). In the first week of October there were five consecutive days where maximum temperature exceeded 35°C (Figure 2B). Maximum temperatures exceeded 28°C everyday between September 28 and October 22.

FIGURE 3: Minimum temperatures (red bars) and grain yield x anthesis date (blue diamonds) for individual plots for bottom slope at Gurley in 2015. Green box indicates the retrospective optimum flowering date at the site.



Retrospectively, the highest yields were achieved when varieties flowered between September 15 and 25 for the bottom slope site at Spring Ridge. Unlike the top slope, the last frost at the bottom slope site occurred on September 30. Frost events in the last week of August appear to have had a significant impact on grain yields of varieties that have flowered prior to September 10. The extent of this frost damage was evident in LPB Dart in the field, where in excess of 90 per cent of primary tillers had frost damage.

Maximum yields for top slope at Gurley were achieved when flowering dates occurred between August 11 and 23. There was one small frost event that occurred during this period. But there were only two frost events that occurred near flowering that were lower than -0.5°C (July 28 and August 5). After October 28 there were 13 consecutive days where maximum temperatures exceeded 28°C and four days where temperatures exceeded 35°C.

For the bottom slope the retrospective optimum flowering dates were between August 24 and September 9. Interestingly, four frost events occurred in this same period (Figure 3). Unlike the top slope there were 17 frosts that occurred between July 27 and August 9 that had minimums below -0.5°C.

To sum up

The data collected in these trials demonstrates why there should be significant motivation to plant paddocks as early as possible to maximise optimal grain filling conditions while avoiding risk of frost damage. On the Liverpool Plains assuming a wheat price of $250 per tonne the late April planting date has created an additional $425 per hectare and $1155 per hectare net return compared to the mid May and early June planting dates, respectively at the top of the slope over three years.

Even in 2016 when optimal spring conditions prevailed there was still a 1.34 tonnes per hectare yield penalty for delaying planting dates from late April to early June at the top of the slope on the Liverpool Plains.

There are few other management tools available to growers that can manipulate net returns to this extent. Admittedly, the 2014 and 2015 seasons exacerbated the impact of planting date due to well below average September rain that was followed by extremely hot weather in early October. Both these factors would have contributed to restricting the grain filling period for long season varieties or later planting dates.

The two locations demonstrate that frost risk can vary greatly within the landscape, particularly with elevation differences. This represents an opportunity for growers to be able to plant earlier in certain parts of the landscape without necessarily increasing their exposure to frost risk.

The top slope sites only had 30 and 20 per cent of the frost events that occurred at the bottom slope on the Liverpool Plains and Gurley, respectively. Not only are there less frost events but the frost severity is also greatly reduced. Top slope sites had 45 per cent higher average minimum temperatures and only accumulated 11 per cent of the time spent <0°C compared to the bottom of the slope when averaged across all sites and locations.

The impact of this drastic difference in frost risk is evident on the April planting date in 2015 at both Spring Ridge and Gurley with the two quicker varieties, LPB Dart and LPB Spitfire. For the bottom slope LPB Dart was 60 and 81 per cent lower yielding compared to the top slope sown in late April at Gurley and Spring Ridge, respectively.

Also on the late April plant LPB Spitfire was 61 and 43 per cent lower yielding at the bottom of the slope compared to the top slope site at Spring Ridge and Gurley, respectively. It was interesting to note that at both Spring Ridge and Gurley, Suntop flowered approximately five days later than LPB Spitfire yet grain yields were 2.4 and 2.7 tonnes per hectare higher, respectively. This suggests that four to five days difference in flowering date could be a difference of 50 per cent in yield losses to frost damage. Varietal difference in tolerance to frost damage may in part also explain some of the differences between LPB Spitfire and Suntop.

Despite the top slope sites at either Gurley or the Liverpool Plains experiencing frost events during all three seasons there was not one instance where significant frost damage was recorded, even in the quickest variety, LPB Dart. Therefore, even earlier planting dates were required at the top slope sites to incur yield penalties from frost.

The significant differences in minimum temperatures between top and bottom slope has also had an interesting impact on crop maturity. The greater number of frost events and severity has in turn slowed down the accumulation of GDD throughout the season, to the extent that the bottom slope at both locations accumulated over 150 GDD less than the top slope. As a direct result of this the crop maturity was delayed. The maturity delay is greatest on the early planting with and average delay of 11 days for varieties to reach flowering.

This is interesting as the delay in maturity is actually helping to negate some of the frost risk at the bottom of the slope. In a majority of cases the optimum flowering window at both Gurley and Liverpool Plains was 14 days later at the bottom of the slope compared to the top slope.

Alarmingly, there were a number of instances where frost events had occurred during the optimum flowering window at the bottom slope sites for both locations. Although these frost events appear to have had little impact on grain yield in these years it does highlight the higher risk of incurring frost damage in these lower parts of the landscape.

Furthermore, it highlights that frost events at lower elevations are persisting longer into the season, yet the onset of potential heat stress is no different to higher elevations, thus reducing the length of the optimum flowering window.

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