Using EL stages and growing degree day data to aid growing season planning

[1]Chelsea Jarvis and [2]Adrian Englefield

[1]Research Fellow, University of Southern Queensland

[2]NSW DPI Development Officer Viticulture

Introduction

Throughout the growing season, grapevines (*Vitis vinifera* L.) go through a number of stages of growth and development, including budburst, flowering, véraison and harvest. The EL stage system categorises the growing stages of grapes, with each major and minor stage associated with a number and description (Table 11). This system was developed by Coombe (1995), then revised by Dry et al. (2004) and is now used worldwide.

Temperature during the growing season influences the timing of the EL stages and is the most important climatic variable for grapevine growth and development.

Growing degree days (GDD, or Winkler index) is a commonly used viticultural tool that categorises growing seasons or a growing region based on the accumulation of temperatures (Table 12). Daily temperatures above 10 °C from 1 October to 30 April are summed to provide a GDD value, expressed as GDD units (°C). GDD can be used to measure heat accumulation over the course of a growing season.

Table 11. Major EL stages for seasonal grapevine growth, adapted from Dry et al. (2004).

Major Stage	EL Number	Description
Budburst	4	Leaf tips visible
Shoots	12	5 leaves separated; shoots about 10 cm long; inflorescence clear
Flowering begins	19	About 16 leaves separated, with first flower caps loosening
Flowering	23	17–20 leaves separated; 50% caps off
Setting	27	Young berries enlarging, bunch at right angles to stem
Berries pea-sized	31	About 7 mm in diameter
Véraison	35	Berries begin to colour and enlarge
Harvest	38	Berries harvest-ripe

How to calculate GDD

1. Option 1: If the daily mean temperature for 1 November 2018 was 28 °C, that one day would contribute 18 GDD units to the monthly total for November (total GDD units is 28 °C - 10 °C base = 18 GDD units). This then needs to be repeated for each day of the month, then added together to get the total GDD for the month.
2. Option 2: Alternately, you can use the mean monthly temperature and multiply it by the number of days in the month. For example, if the mean monthly temperature for November 2018 was 28 °C, the calculation of the growing degree days for all of November would be as follows: 28 °C - 10 °C (base) = 18 °C; 18 GDD units × 30 (number of days in November) = 540 GDD units total for the month of November.

Table 12. Range of GDD values accumulated between 1 October and 30 April corresponding to defined categories.

Category	GDD Range	Variety suitability
Too cool	< 850	Too cool to fully ripen most *V. vinifera L* varieties
Region I	851–1389	Early ripening varieties, sparkling wine
Region II	1389–1667	Early and mid-season varieties
Region III	1667–1944	Quality production of most varieties
Region IV	1944–2222	Later ripening varieties, lower quality for other varieties
Region V	2222–2700	Suitable for high production with lower quality
Too hot	> 2700	Too hot for quality production of most *V. vinifera L* varieties

GDD values during the growing season can also be compared with the timing of EL stages. For example, if the dates of flowering and véraison are recorded, GDD can be calculated for the time period between the two stages to provide the grower with an approximation of how many GDD units are required for the grapes to reach véraison following flowering.

EL Stages and GDD for the Riverina, NSW for the 2017–18 growing season

For this study, EL stages were recorded for nine different vineyard blocks during the 2017–18 growing season. The vineyard blocks were located in three different locations: Kooba, Nericon and Yenda, all of which are in the vicinity of Griffith, NSW. Observation of EL stages were made by Adrian Englefield (NSW DPI Development Officer Viticulture). Baumé (Bé) and titratable acidity (TA) samples were assessed at the National Wine and Grape Industry Centre (NWGIC) winery leading up to harvest.

Each vineyard location had a DPI weather station located within the vineyard block. Growers can view and download weather and climate data from eight NSW wine regions from this weather station network (www.dpi.nsw.gov.au/agriculture/horticulture/grapes). If your area is not available on the NSW DPI website, also check the Australian Bureau of Meteorology website (www.bom.gov.au/climate/data/), where you can download rainfall or temperature data from weather stations across Australia.

Vineyard observations using the EL stage descriptions were made 11 times between 8 September 2017 and 12 February 2018 to provide a comprehensive picture of the growing season from budburst to harvest. GDD data was downloaded from the DPI weather station network website. Mean growing season temperature (MGST) was also calculated for the vineyard sites used in this study. Table 13 shows total GDD units for the 2017–18 season (1 October to 30 April), MGST, as well as varieties grown at each location and dates of observed major EL stages.

Using the EL data collected for the 2017–18 growing season along with GDD data from the NSW DPI website, we compared EL stage and GDD unit accumulation. Figure 68 shows the number of GDD units that correspond to EL stage for all vineyards in this study for the 2017–18 growing season.

Later development stages require more GDD units than earlier stages, with the change happening around stage 32, which is when the berries are pea-sized and are starting to touch (beginning of bunch closure). Stages 2 (bud scales opening) to 32 required approximately 750 GDD units, while the stages from 33 (berries still hard and green) to 38 (harvest) required over 1000 GDD units, even though there were fewer stages. This example shows that different EL stages require different GDD units (Figure 68).

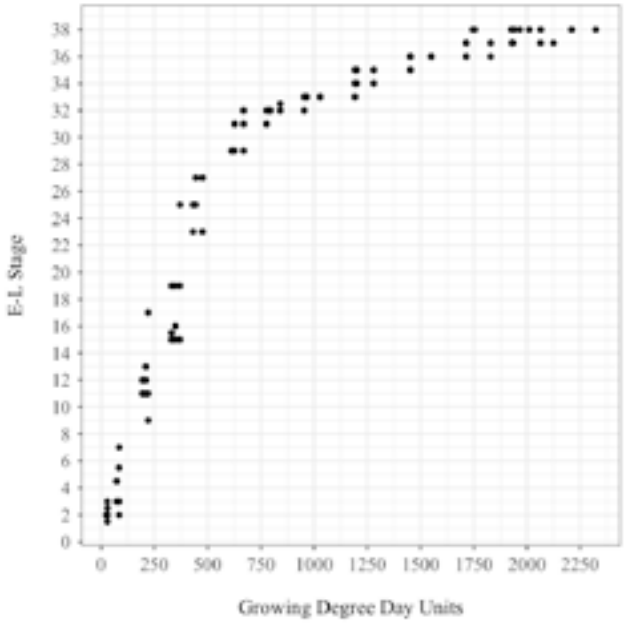

Figure 68. EL stage corresponding to GDD units (°C) for all vineyards included in this study for the 2017–18 growing season.

Table 13. Vineyard locations and varieties, including GDD and MGST values for each location and major EL stages for all vineyard blocks.

Vineyard location	GDD 2018	MGST 2018 (°C)	Variety	Date budburst	Date flowering	Date véraison	Date harvest
Kooba	2728	22.9	Chardonnay	18-Sep	30-Oct	29-Dec	22-Feb
			Merlot	22-Sep	3-Nov	15-Jan	13-Mar
			Pinot Gris	22-Sep	31-Oct	7-Jan	13-Feb
Nericon	2931	23.8	Chardonnay	11-Sep	18-Oct	7-Jan	5-Feb
			Durif	25-Sep	3-Nov	29-Dec	22-Feb
			Pinot Gris	22-Sep	28-Oct	29-Dec	9-Feb
Yenda	2832	21.6	Chardonnay	14-Sep	28-Oct	29-Dec	31-Jan
			Pinot Gris	22-Sep	20-Oct	29-Dec	1-Feb
			Semillon	22-Sep	1-Nov	15-Jan	15-Feb

GDD can be used to estimate the timing of EL stages. Each stage requires a certain amount of GDD units, although the number of units required will vary depending on variety, rootstock, location and other environmental influences such as rain and management techniques. The number of GDD units required for the four main phenological stages for Pinot Gris from each of the vineyard locations included in this study are shown in Table 14. Note that GDD unit accumulation started on 1 September. Harvest times have been adjusted slightly to represent the day that all three vineyards would have reached 11.7 Baumé, so that comparisons of ripeness are the same for all vineyard blocks.

All three Pinot Gris blocks had budburst on 22 September (Table 13) and GDD units accumulated between 1–22 September varied slightly by location (Table 14). As the Pinot Gris at each vineyard progressed through the growing season, the GDD units needed to ripen the fruit varied by block, with Nericon needing fewer GDD units to reach 11.7°Bé than either Kooba or Yenda. This could be due to clone, rootstock, irrigation or other management techniques. For this reason, it is important to establish EL stage timelines for each individual vineyard block, as GDD units required for growth and ripening can vary significantly, even for the same variety.

The number of GDD units accumulated for each month and daily averaged values (total monthly accumulation of GDD divided by number of days in the month) varied by both location and month (Table 15). Estimates of daily values can be used to calculate the likely date of future stages, if the amount of GDD units required by stage is known.

The best way to use GDD to estimate EL stages is to record the EL stages for a number of growing seasons (ideally at least five) to ensure that the data is a good representation of an average vintage. Then, download the GDD data from the DPI website for the same vintages to determine how many GDD units (on average) are required for each EL stage for a particular vineyard.

Table 14. Total number of GDD units recorded for each major EL stage for Pinot Gris at each vineyard location. GDD unit accumulation started on 1 September. Corresponding dates for the major EL stages are in Table 11.

Stage number and description	4 Budburst	23 Flowering	35 Véraison	38 Harvest (11.7°Bé)
Kooba	66	338	1324	1893
Nericon	76	405	1285	1469
Yenda	70	403	1449	1965

How to use GDD to estimate EL stages for your vineyard

Calculating average GDD units accumulated by day is a good way to estimate the timing of a future EL stage. For example, if you know that the Pinot Gris in Yenda requires 400 GDD units to reach flowering and it is currently the 15 October and, so far this season, 270 GDD units have accumulated since 1 September, you need an additional 130 GDD units before the Pinot Gris will be at flowering stage. Looking at Table 15, we see that for the month of October, there are approximately 8.5 GDD accumulated for each day. The calculation of 130 ÷ 8.5 gives you 15 days. Therefore, the Pinot Gris should be at flowering stage on approximately the 30 October.

Comparing historical EL stages with the 2017–18 Riverina growing season

The EL stages of vineyards in the Riverina area for 1966–70 was reported by Due et al. (1993). Comparing this with current data, the timing of EL stages and GDD values have changed over time. Table 16 summarises the reported EL stages, with both date and corresponding day-of-year listed for both time periods.

Converting a date (e.g. 1 November 2018) to 'day of year' can be useful when tracking EL stages or GDD accumulation. Day of year (DOY) is usually the number of days after 1 January. Because the growing season occurs over two different years

Table 15. Total monthly accumulation and daily average accumulation of GDD units for the months of August to April for the 2017–18 growing season.

Location	Totals	August	September	October	November	December	January	February	March	April
Kooba	Monthly total	21	131	265	374	450	530	422	386	302
	Daily average	0.7	4.4	8.5	12.5	14.5	17.0	15.0	12.5	10.1
Nericon	Monthly total	29	147	284	396	489	560	458	415	330
	Daily average	0.9	4.9	9.2	13.2	15.8	18.1	16.4	13.4	11.0
Yenda	Monthly total	39	138	262	381	438	524	418	384	289
	Daily average	1.3	4.6	8.5	12.7	14.1	16.9	14.9	12.4	9.6

(2017 and 2018), we add 365 to any date occurring after 1 January 2018. For example, the DOY for 1 November 2017 is 305 because it is the 305th day of the year; the DOY for 1 February 2018 would be 397 (365 + 32). Changing a date to a DOY makes it easier to calculate the number of days between two events.

EL stage dates have changed for some stages (flowering and harvest) but not for others (budburst). Budburst occurs, on average, on 20 September, for both time periods. However, in the 2017–18 season, flowering was advanced by 15 days and harvest advanced by 26 days compared to the 1966–70 seasons. The DOY variable is helpful here as it makes it easier to determine the differences in days between the two time periods (Table 16). For example, the mean harvest DOY in the earlier time period was 436, compared with 410 in the later time period, so it has changed by 26 days. This is an easier calculation than determining the number of days between the two periods using the calendar dates of 12 March and 12 February.

Accumulated GDD units for August have not changed between the two time periods (Table 16). This could be why the date of budburst also has not changed. The 2014–18 time period has, on average, an additional 473 GDD units per growing season, or 22% more GDD units than the 1966–70 average. The decrease in number of days in the growing season is likely due to the warmer temperatures experienced in recent years, as reflected in the increase in GDD values. Temperatures have had the greatest increases for December, March and November. Given that most grapes are picked before the end of March, the increased temperatures in December and November are likely to have the most impact.

Traditionally, GDD units per growing season are calculated from 1 October to 30 April. For many vineyards in Australia, the growing season begins in September and finishes before April. This suggests that there should be a shift in the calculation of annual GDD to include September and remove April. A recent study (Jarvis et al. 2017) showed that this shift of months improved the correlation between GDD and day of winegrape maturity. For growers, it is most advantageous to use whichever months best suit their growing conditions. However, when comparing the GDD units of one region to another, for example comparing GDD units of Griffith, NSW to Napa, California, you should use the traditional months as this is the international standard.

Comparing GDD and EL stages for multiple growing seasons

Other researchers who have used GDD in studies noticed that, when compared to DOY as opposed to EL stage, the relationship was almost linear (Figure 69). It was then deduced that there is an inherent correlation between accumulated time and accumulated temperature, such that comparing GDD to DOY of EL stages over the course of one entire season would not be useful.

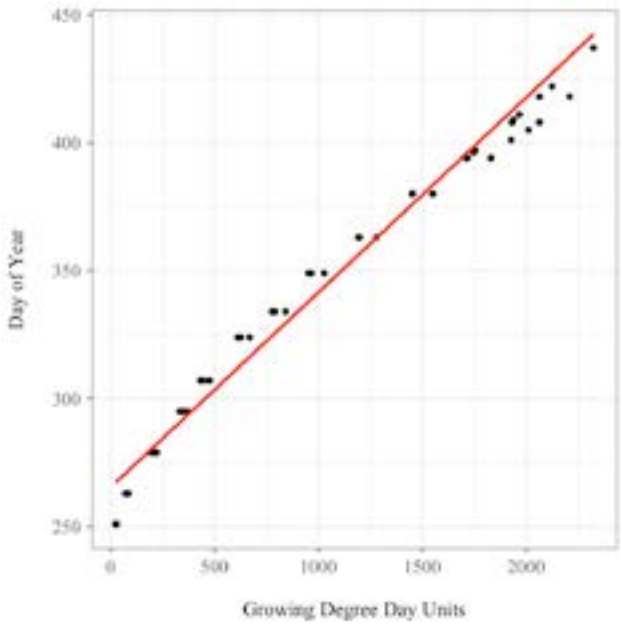

Figure 69. DOY for EL stages corresponding to GDD units (°C) for the vineyards included in this study for the 2017–18 growing season. $R^2 = 0.9748$, $p<0.01$.

Table 16. Average GDD units accumulated for each month for two time periods, 1966–70 and 2014–18.

	August	September	October	November	December	January	February	March	April	GDD total (October–April)
1966–1970	34	78	208	260	361	439	403	318	197	2184
2014–2018	34	114	253	343	453	508	449	402	248	2657
Difference	0	36	45	83	92	69	46	84	51	473

It would be useful, however, to compare variables such as GDD or EL stage if you are looking at one variable for multiple years of data. For example, when looking at harvest timing (EL38) over the course of a number of years, stage 38 has occurred earlier in the season in recent years (Figure 70). GDD values have increased over the same period of time (Figure 71). Therefore, it is likely that earlier harvest times (EL38) are linked to warmer growing seasons.

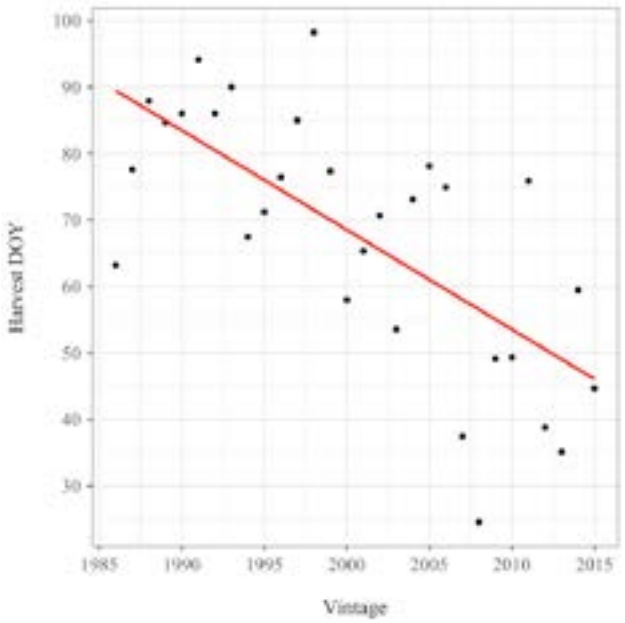

Figure 70. Harvest DOY for Barossa Valley Shiraz for the 1986–2015 vintages. $R^2 = 0.4745$, $p<0.01$.

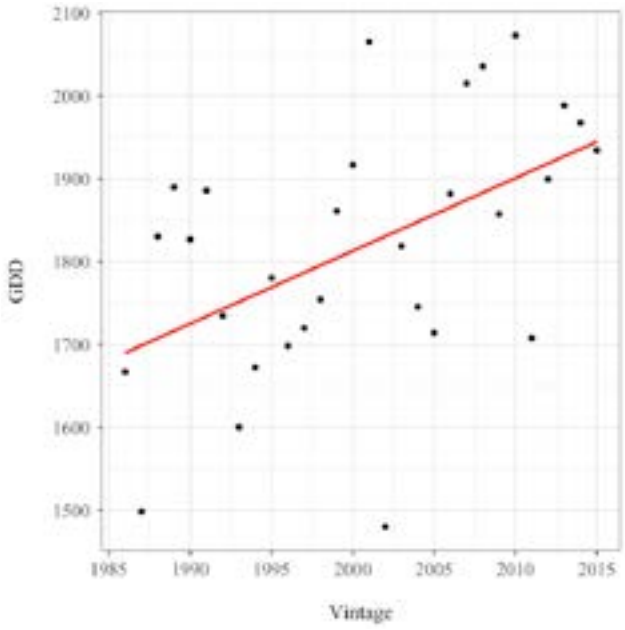

Figure 71. GDD for September–March for the Barossa Valley 1986–2015 vintages. $R^2 = 0.2539$, $P<0.01$.

Baumé, titratable acidity and GDD

Baumé (Bé) and titratable acidity (TA) were recorded for each of the nine vineyard blocks in the lead up to harvest. As expected, TA levels decreased as Bé increased. Bé for the Kooba Chardonnay increased at a rate of 0.008 per GDD unit and TA decreased by 0.013 per GDD unit (Table 17). For convenience, Bé and TA are also shown as change per 100 GDD units. During harvest time for the Griffith area, each day accumulates between 15 and 20 GDD units, thus 100 GDD units would accumulate over 5 to 7 days.

With the exception of the Yenda Pinot Gris, all the vineyard blocks had TA decreasing at a faster rate than Bé increased. For the Nericon and Yenda Chardonnay blocks, TA decreased almost twice as fast as Bé increased. The Kooba Chardonnay and Merlot were similar, with TA decreasing more rapidly than Bé.

Using GDD data along with Bé and TA data can aid in estimating when the fruit will be ready for harvest and could potentially reduce the number of sampling days needed. Collecting Bé and TA data for a number of seasons and then combining this information with GDD information from the DPI website, informed decisions regarding scheduling harvest and better management of Bé and TA levels in the grapes can be made.

Conclusion

Combining GDD and EL stage data can be a helpful tool in estimating phenological timing, Bé and TA values. It can also be helpful with planning the growing season. For many winegrowing areas in NSW, there are freely available weather station data sets that include daily GDD values. Each variety and vineyard block will have different GDD requirements for each EL stage, so it is important to collect EL stage data from each vineyard block for the best accuracy. When looking at the timing of EL stages and how they have changed over time, it can be convenient to convert a date into a DOY variable. DOY is also useful when comparing the same EL stage for multiple years. However, DOY for EL stages for only one growing season should not be compared directly to GDD for that same growing season due to the relationship between accumulated time and accumulated GDD units.

Comparing the 1966–70 and 2017–18 growing seasons, the timing of budburst has not changed yet, but flowering is now, on average, 15 days

earlier and harvest is 26 days earlier for the Riverina area. This indicates that the amount of time between the growing stages has shortened, rather than an earlier start to the season leading to an earlier season. Changes such as these can be tracked using GDD and EL stage information.

Table 17. Rates of change in Bé and TA values per GDD unit and per 100 GDD units for all vineyard blocks for the 2017–18 growing season. Rates listed for Bé units are positive, since they are increasing per GDD unit(s) and rates listed for TA units are negative, as they are decreasing per GDD unit(s).

Vineyard	Variety	Rate Bé (positive) per GDD unit	Rate TA (negative) per GDD unit	Rate Bé (positive) per 100 GDD units	Rate TA (negative) per 100 GDD units
Kooba	Chardonnay	0.008	-0.013	0.8	-1.3
	Merlot	0.011	-0.016	1.1	-1.6
	Pinot Gris	0.009	-0.011	0.9	-1.1
Nericon	Chardonnay	0.004	-0.007	0.4	-0.7
	Durif	0.012	-0.016	1.2	-1.6
	Pinot Gris	0.009	-0.010	0.9	-1.0
Yenda	Chardonnay	0.008	-0.015	0.8	-1.5
	Pinot Gris	0.011	-0.010	1.1	-1.0
	Semillon	0.009	-0.011	0.9	-1.1

Further information and acknowledgements

Adrian Englefield, NSW DPI Development Officer Viticulture
adrian.englefield@dpi.nsw.gov.au

Chelsea Jarvis, Research Fellow, University of Southern Queensland
chelsea.jarvis@usq.edu.au

Wine Australia Riverina Regional Program 2017–18

Wine Grapes Marketing Board

References

Coombe, BG 1995, 'Growth stages of the grapevine: adoption of a system for identifying grapevine growth stages', *Australian Journal of Grape and Wine Research*, 1: 104–110.

Dry, PR, Coombe, BG and Anderson, CJ 2004, *Viticulture*, Winetitles, Adelaide.

Due G, Morris M, Pattison S and Coombe BG 1993, 'Modelling grapevine phenology against weather: considerations based on a large data set, *Agricultural and Forest Meteorology*, 65: 91–106.

Jarvis, C, Barlow, E, Darbyshire, R, Eckard, R and Goodwin, I 2017, 'Relationship between viticultural climatic indices and grape maturity in Australia', *International Journal of Biometeorology*, 61: 1849–1862.