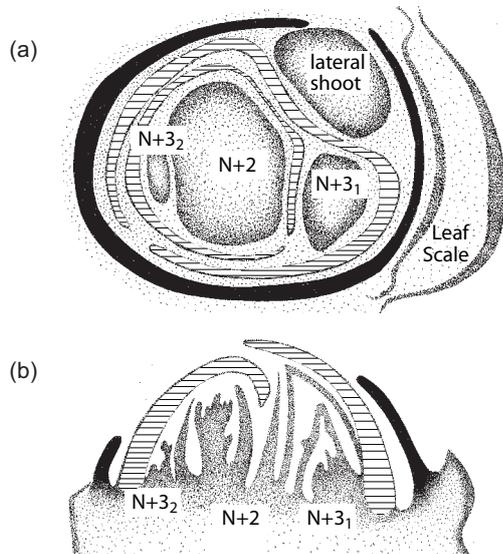


Grapevine structure and function

2.3.7 THE COMPOUND BUD

The term 'compound bud' (also called the 'eye') is used to describe a structure which contains several buds (Figures 2.18 and 2.19). Each bud within the compound bud has the potential to develop into a shoot, and thus it can be thought of as a compressed shoot.



Figures 2.18 A diagrammatic representation of the positioning of latent buds within a compound bud — (a) a transverse section; (b) a longitudinal section (redrawn and modified from Pratt 1974, used with permission from the American Society for Enology and Viticulture).

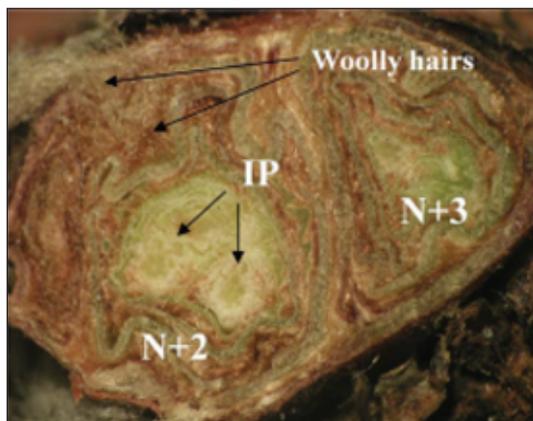


Figure 2.19 A transverse section of a compound bud, showing the N+2 with inflorescence primordia (IP) clearly visible and an N+3 bud (photograph C. Collins).

Some more terminology — a bract is a small, scale-like leaf structure. If a bract is formed at a node on a stem, it is called a prophyll. Note that May (2000) uses the term stipule, whereas other authors, e.g. Pratt (1974) and Mullins et al. (1992), use the term prophyll to describe a bract. In this book we use the term prophyll.

In the formation of a lateral shoot, the first leaf of the lateral shoot is reduced to a prophyll. The bud which develops in the axil of the basal prophyll of the lateral shoot is the N+2 primary bud. This bud, which is essentially a primordial shoot, is called a latent bud because it does not normally burst until the following growing season.

Before entering dormancy, this primordial shoot forms up to 12 nodes (but usually 6 to 10), all with leaf primordia and some with leaf-opposed inflorescence or tendrill primordia.

The N+2 bud is the central and largest bud of the compound bud. There are vascular connections between N+1 and N+2 buds.

The two or sometimes three basal nodes formed in an N+2 bud carry only prophylls without leaf primordia (as is the case of the basal node of an N+1 bud) and the buds in the axils of these prophylls are coded N+3. There is minimal internodal elongation between these prophylls. These N+3 buds are usually called secondary buds. For convenience, the larger and most proximal of these is often called 'the secondary bud' and the smaller 'the tertiary bud' — however this usage may be confusing because it implies, incorrectly, that they are of different generations. Therefore, it is preferable to refer to them as N+3₁ and N+3₂ respectively (Figures 2.18, 2.19 and 2.20).

The N+2 and N+3 buds are enclosed in bud scales (the prophylls of the N+1 and N+2 buds respectively) and collectively form the compound bud (Figures 2.18).

Prompt (N+1) buds grow into lateral shoots, whereas N+2 and N+3 buds of compound buds grow into main shoots.

Leaf primordia are not present on nodes where buds are well-developed, i.e. where the N+2 bud is situated on the N+1 bud, or where N+3₁ and N+3₂ (and sometimes N+3₃) buds are situated on the N+2 bud. In contrast, more distal nodes formed in an N+2 bud carry well-formed leaf primordia but have much smaller bud primordia in their axils.

May (2000) speculates that the presence or absence of a leaf primordium may have a determining effect on the development of the associated axillary bud. If the development of the N+2 bud is disrupted in any way, e.g. as in the case of primary bud necrosis (PBN) (as described in Dry and Coombe 1994), the N+3₁, N+3₂ and N+3₃ buds develop much more and will be larger than usual (Figure 2.20). If an N+2 bud is damaged, e.g. through the occurrence of PBN or a frost event, shoots may develop from N+3 buds. These may bear inflorescences, and thus some yield may still be obtained. The impact on yield will depend on the extent of bud loss and the capability of the vines to produce bunches on shoots from N+3 buds or on shoots that have arisen from base buds (Howell 2001).

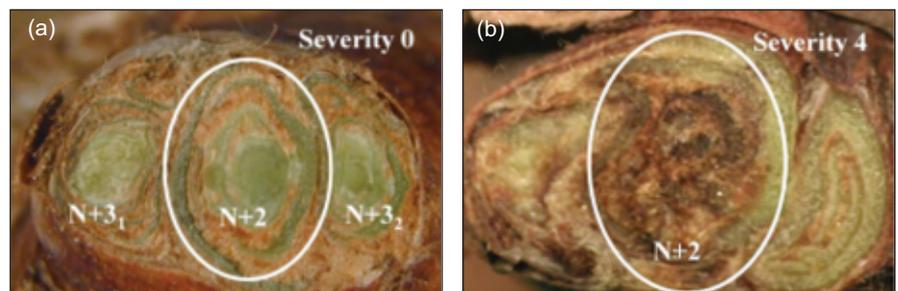


Figure 2.20 (a) a normal N+2 bud with a severity rating of the degree of necrosis of 0 and (b) a necrotic N+2 bud with a severity rating of the degree of necrosis of 4: compare the colour and structure of two buds (photographs C. Collins).

Grapevine structure and function

2.3.13 THE BUNCH

The bunch is a fertilised inflorescence. Initially, the inflorescence maintains an erect position, but after fertilisation and fruitset the weight of the berries causes the bunch to hang downwards.

The structure of the bunch is the same as that described for the inflorescence (see Figure 2.29). Bunch length, width and weight can vary widely depending on variety and cultural practices (Figure 2.36).



Figure 2.36 Different sizes and weights of Cabernet Sauvignon bunches (photograph T. Proffitt).

Bunch shape is one of the characteristics used in ampelography. However, for any variety, bunch characteristics can vary due to pruning method, irrigation and other cultural practices.

Incidence of diseases such as downy mildew (*Plasmopara viticola*) and pests such as caterpillars and weevils may also influence the appearance of a bunch. The physiological disorder 'bunchstem necrosis' creates dried-up sections of the rachis and causes the berries to shrivel and become necrotic.

When vines are mechanically harvested the berries are shaken off the rachis, which usually remains attached to the shoot (Figure 2.37). The berries are collected in trays inside the mechanical harvester and transferred, via a conveyor belt, to bins, which are then transported to the winery.



Figure 2.37 The rachis after the vine has been mechanically harvested (photograph T. Proffitt).

2.3.14 THE BERRY

The berry is made up of seeds, flesh and skin (Figure 2.38). The proportion of the total weight of the berry made up by the weight of each component varies with variety, environment and cultural practices. As a guide, the proportional weights for seeds, flesh and skin are in the order of 5, 80 and 15% respectively. A powdery waxy coating, called the bloom, covers the outside of the berry. The anatomy of the berry is shown in Figure 2.39.

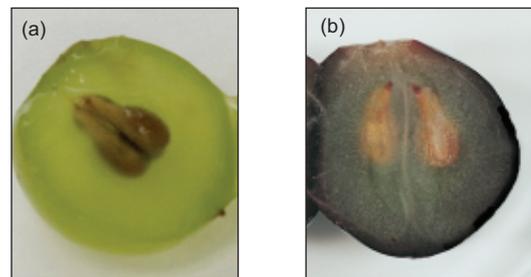


Figure 2.38 (a) A white and (b) a black grape berry cut into halves (photographs E. Wilkes).

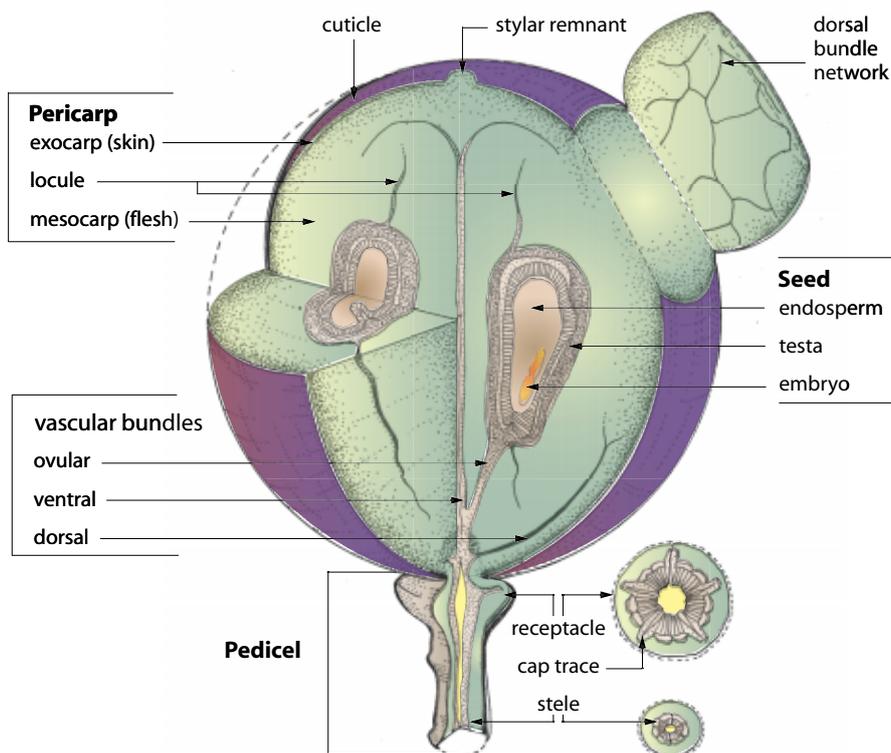


Figure 2.39 Structural components of the berry (adapted from a figure in Coombe 1987, used with permission from the American Society for Enology and Viticulture).

6.4 FRUITSET

Coombe (1962) defines fruitset in plants as the changeover from the static condition of a flower ovary to the rapidly growing condition of a young fruit — in the case of the grapevine, from an ovary to a berry. However, only a proportion of flowers completes fruitset successfully.

For grapevines, when fruitset is successful a single grape flower develops into a single grape berry (Figure 6.3). Fruitset of grapevine flowers requires two independently-controlled processes to take place: a) resumption of cell division in the pericarp and b) prevention of abscission layer activation at the base of the pedicel (Mullins et al. 1992).

Failure of flowers to develop into fruits is a common phenomenon in horticultural plants. The % fruitset may be as low as 0.01% for avocado and mango (Sedgley and Griffin 1989). For most crops, initial fruitset is relatively high but the fruitlets subsequently drop in large numbers. However, this delayed drop does not take place with grapevines and the proportion of flowers that develop into berries is normally determined within 2 to 3 weeks of the start of flowering. The % fruitset for grapevine flowers varies widely. As a guide, large inflorescences with 300 to 1500 flowers generally have 15 to 30% fruitset, whereas small inflorescences with 100 to 250 flowers can range from 20 to 60% fruitset.

After fertilisation and fruitset, the stigma and style dry up, leaving a small black scar at the polar end of the young berry.

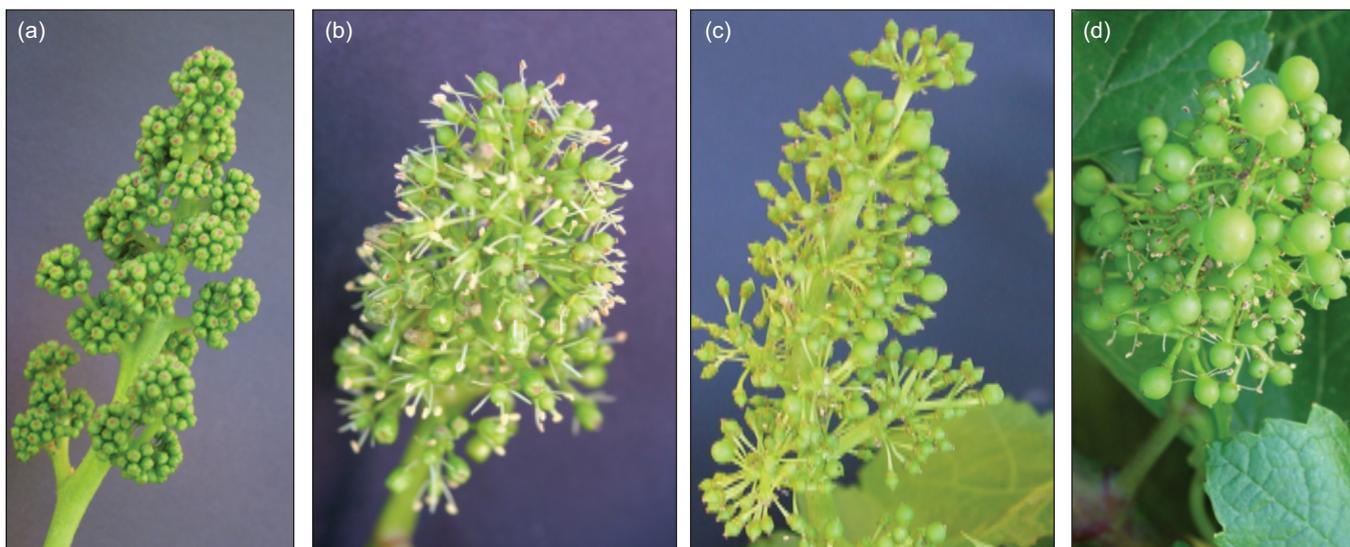
Fruitset is one of the major yield-determining events each season and accounts for much of the between-season variation in some regions.

In viticulture, we use the term percentage fruitset to quantify the proportion of ovaries that develop into berries; the calculation is shown in Equation 6.1.

% fruitset = (number of berries/number of flowers) x 100.

% fruitset can be expressed on either a per bunch or a per vine basis.

Equation 6.1 Calculation for determining percentage fruitset.



Figures 6.3 (a) Flowers with caps still attached, (b) flowering, (c) berries formed at fruitset and (d) berries after fruitset (photographs M.A. Bottger).

? *How is % fruitset measured?* The only accurate method is to count the number of flowers per inflorescence before flowering and the number of berries per bunch after fruitset. You may come across some publications where the % fruitset has been inferred solely from a count of berries per bunch — this is inappropriate because it has been assumed incorrectly in the majority of cases that the flower number is a constant on each bunch. Because actual counting of all flowers on an inflorescence is very laborious, many methods have been developed for estimating flower number (May 2004, Poni et al. 2009). The most accurate direct method is to bag the inflorescence before flowering and count flower caps that have fallen into the bag after fruitset. Indirect methods include use of regressions of inflorescence length or branch number with flower number.

? *What determines % fruitset?* Many factors interact to determine the proportion of flowers that develop into berries. They include variety and rootstock, water supply and mineral nutrition, shoot vigour, bunch number and size, and climatic conditions.

Some varieties are genetically predisposed to low % fruitset, particularly in association with unfavourable climatic conditions, e.g. Cabernet Franc, Cabernet Sauvignon, Chardonnay, Grenache, Merlot and Riesling. In general, but not exclusively, such varieties tend to have loose rather than compact bunches.

Percentage fruitset on an individual bunch is inversely proportional to bunch number per vine.

6.5 TYPES OF FRUITSET

6.5.1 STIMULATIVE PARTHENO-CARPY

True parthenocarpy does not occur in grapevines (May 2004). However, in the case of Zante Currant, stimulation of pollination, i.e. deposition and germination of pollen, is sufficient to induce set and cause berry development. In this case, flowers are hermaphroditic but there is no ovule development after flowering. Percentage fruitset is relatively low and final berry size is very small. Fruitset can be improved and berry size increased by cultural practices such as girdling (cincturing) and the use of hormone sprays.

Water, soil and the vine

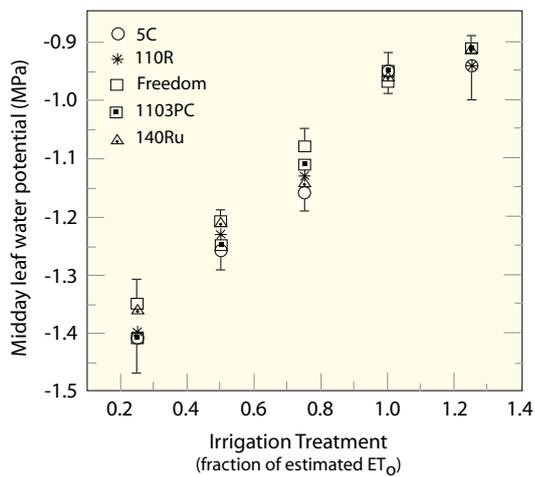


Figure 11.2 Midday leaf water potential of Cabernet Sauvignon vines as a function of rootstock and applied water amounts. Values are the means of measurements taken close to harvest each year of the study. Bars represent one standard error (redrawn from Figure 2 in Williams 2010, used with permission from the Australian Society of Viticulture and Oenology).

11A.3 WATER MOVEMENT INTO AND OUT OF LEAVES

11A.3.1 TRANSPIRATION RATE

Vines continually absorb and lose water. Both leaves and berries transpire, but most of the loss of water is through leaf transpiration. Leaves are the main sites where the vine regulates its water loss.

11A.3.2 LEAF WATER POTENTIAL

Diurnal cycle of leaf water potential

During the night, stomates close, transpiration slows or stops and leaf water potential rises (changes to a less negative value) as the vine gradually re-hydrates and leaf water potential equilibrates with soil water potential. Equilibration takes place sometime towards the end of the night. The highest leaf water potential (lowest negative value) is achieved pre-dawn. After sunrise, the stomates open, transpiration takes place and the leaf water potential starts to decrease (changes to a higher negative value). At some point during the day, often around solar noon, the point of lowest (highest negative value) leaf water potential is reached, after which time leaf water potential rises (Figures 11.3, 11.4).

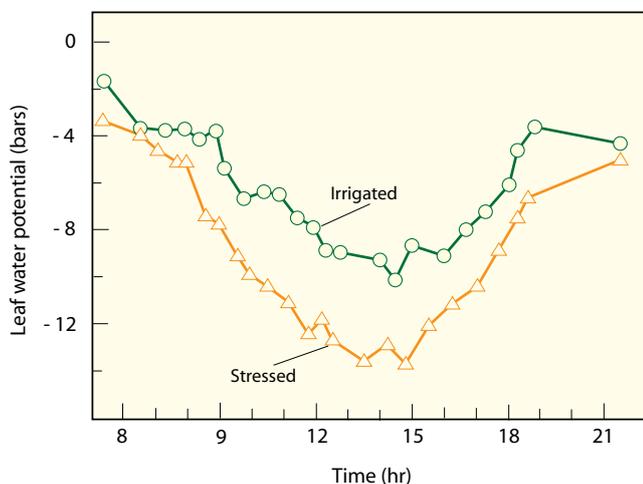


Figure 11.3 Diurnal change in leaf water potential of well-watered and stressed vines (adapted from Figure 6 in Smart 1974, used with permission from the American Society for Enology and Viticulture).

At night an equilibrium is normally achieved below and above the ground and the measure of pre-dawn leaf water potential, provided that the equilibrium state has been attained, can be taken as an indicator of the average soil water potential.

Change in leaf water potential of water-restricted vines

The leaf water potential of water-restricted vines is lower (higher negative value) than that of well-watered vines and the lowest value is normally achieved earlier in the day (Figure 11.4).

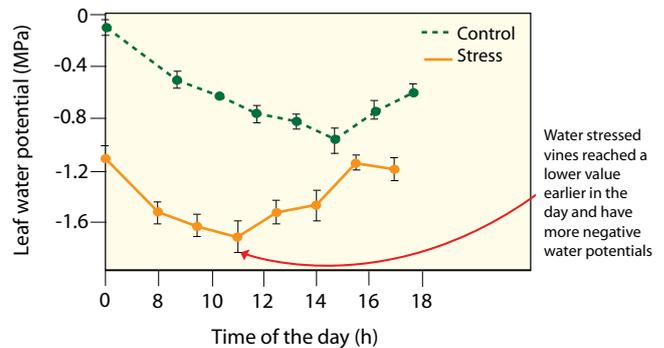


Figure 11.4 Diurnal change in leaf water potential of well-watered and water-restricted vines (adapted from Figure 1a in Rodrigues et al.1993, used with permission from CSIRO Publishing).

Typically, if soil water availability decreases, leaf water potential gradually declines (moves to a higher negative value). An example of the change in leaf water potential for potted Chardonnay vines over several days is shown in Figure 11.5. Note that in this example leaf water potential measures were taken using a psychrometer. The pre-dawn leaf water potentials (the lowest points in each daily cycle of Figure 11.5) are probably close to the water potential of the soil.

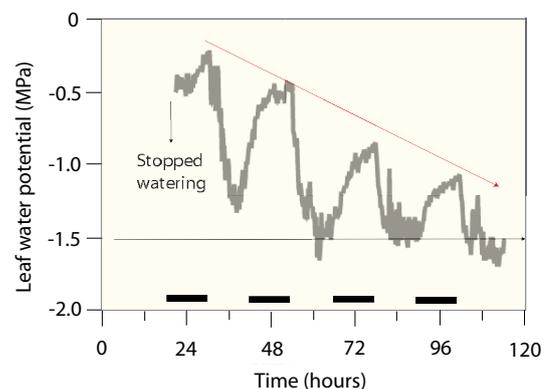


Figure 11.5 The change in leaf water potential (measured by a psychrometer) when water supply was restricted to the roots of potted Chardonnay vines (figure provided by S.D. Tyerman).

As the soil dries it becomes increasingly difficult for the vine to extract water from the soil. Depending on atmospheric conditions and if water availability continues to decrease, it is likely that, at some stage a point is reached at which the vine can no longer lower its water potential and therefore cannot extract water from the soil. This point is referred to as the permanent wilting point. The permanent wilting point for grapevines varies with variety, rootstock, weather and soil type but generally this happens when leaf water potential is about -1.5 MPa.

Climate and the vine

Well-watered vines exposed to severe heat stress can recover rapidly and suffer minimal damage (Edwards 2009, Webb et al. 2009a,b). However, leaf loss may be high during a high temperature event when the vine is water stressed. If a heatwave is forecast, irrigation should be applied before the start of the heatwave and continued frequently (every day) throughout the heatwave. It is important to maintain adequate vine nutritional status so that leaves are in the best state to resist stress conditions and thus maintain leaf function.

During a heatwave it is critical to irrigate vines.

Spraying water over the canopy via the use of overhead sprinkler systems is another option for cooling canopies — bunch temperature can be reduced by 8 to 15°C (Kliewer and Torres 1972). Issues of water availability, salt damage and disease need to be considered for this approach (Dry 2009, Dry et al. 2009).

Products known as ‘sun-protection’ agents — applied as foliar/bunch sprays — are currently being trialled as a means to protect bunches from high temperature/solar radiation damage (Dry 2009, Dry et al. 2009, Scarlett 2009).

12.11 TEMPERATURE CONDITIONS DURING BERRY RIPENING

Several approaches have been used to describe temperature conditions during berry ripening, for example, ‘heat summation’, ‘ripening month average temperature’, ‘heat accumulation indices’ and ‘optimal temperature range for anthocyanin synthesis’.

Gladstones (2004) used the concept of ‘ripening month average temperature’ to develop a model to link wine style with a range of climatic elements. His arguments are based on the effect of temperature on the activity of enzymes involved in flavour metabolism in berries, and particularly those in berry skins.

The study of Spayd et al. (2002) examined the concept of ‘accumulated temperature’ and ‘the length of time that berries are subjected to specific temperatures’ over the growing season. Threshold temperatures of 30, 35 and 40°C were selected to determine the effect of ‘high temperature duration’ for berries positioned in different parts of the canopy. This concept may also be applied to the ripening phase of berry development.

Happ (1999a,b) proposed a ‘heat work index’ for evaluating flavour development and conservation in grape berries.

Iland and Fetzmann (2000) proposed a ‘potential anthocyanin production capacity’ by calculating the percentage of time that the ripening phase falls within the optimal temperature range for anthocyanin synthesis (Figure 12.25). Daily maximum and minimum temperatures were used to construct the graphs. In this case, the percentage of the time period that was above, within and below ‘the selected optimal temperature range’ was 4, 58 and 38%, respectively. 1990 was considered an excellent year (D. Fetzmann, pers. comm).

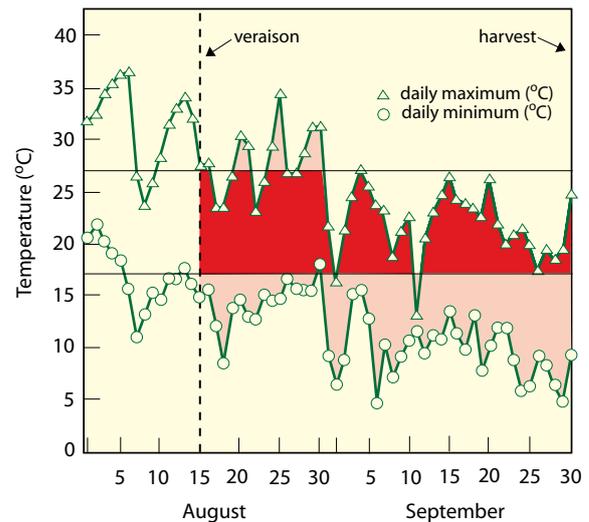


Figure 12.25 The change in daily minimum and maximum temperature during the period veraison to harvest for a site in Burgundy during the 1990 vintage. The horizontal lines represent ‘the selected optimal temperature range’ for anthocyanin production and the shaded dark red area indicates the section of the temperature profile that falls within that range (from Iland and Fetzmann 2000).

A similar approach can be used with data from automatic weather stations or data loggers where the temperature is recorded on an hourly basis or continuously (see Figure 12.26). In this case (Figure 12.26), the percentage of the time period that was above, within and below ‘the selected optimal temperature range’ was 15, 68 and 17% and 39, 57 and 4% for the 2002 and 2003 vintages, respectively. Wine quality was generally considered to be better in 2002 than in 2003.



Figure 12.24 Heat damaged berries on (a) the day, (b) one day after and (c) one week after a heatwave event (photographs T. Proffitt).

Example 14.2

Proffitt et al. (2000)

Variety/Location: Cabernet Sauvignon/Coonawarra, Australia.

This site is relatively flat with an elevation ranging between 50 and 60 m above sea level. The region is classified as 'cool to temperate' with long, mild summers, cool autumns, and cold wet winters (Dry et al. 2004).

Treatments: Comparison of vine growth characteristics, berry composition and wine sensory attributes from two soil types — a red to red-brown 'terra rossa' and a 'deep black cracking clay' (Figure 14.4).



Figure 14.4 (a) The 'terra rossa' soil and (b) the 'deep black cracking clay' soil (photographs P.G. Iland).

These soils occur in close proximity. Because the topography is flat and management practices are generally similar, the 'terroir' of each site is largely determined by soil characteristics.

For the winemaking exercise, the fruit from each site was harvested at a similar maturity: 13°Baumé.

Results and discussion: The properties of each soil type are described in Table 14.1 — values are averaged over the vine rooting depth.

The deep black cracking clay soil has a heavier topsoil and subsoil texture, a deeper and more extensive root system and a greater water holding capacity than the shallower terra rossa soil.

Table 14.1 Properties of the terra rossa and the deep black cracking clay soils (data sourced from Proffitt et al. 2000).

Property	Terra rossa soil	Black cracking clay soil
Texture	Clay loam/loamy clay	Medium clay/heavy clay
Plant available water (mm)	63	96
Stress available water (mm)	41	64
Readily available water (mm)	25	40
Total porosity (%)	52	49
Airfilled porosity @ 10kPa (%)	19	11
Bulk density (g/cm ³)	1.3	1.4
Soil strength @ 10kPa (MPa)	1.7	2.9
Organic carbon (%)	1.6	1.6
pH (CaCl ₂)	7.1	6.6
ECe (dS/m)	1.5	0.6

Both soils have organic carbon levels which are adequate and pH values close to neutral. Saturation extract (ECe) values indicate that neither soil has a salinity problem.

Sapflow sensor data showed that vine water use (mm/day) was consistently greater for vines grown on the deep black cracking clay soil than for vines grown on the terra rossa soil. This is partly due to the larger canopy of vines on the deep black cracking clay soil, but even when expressed on a leaf area basis (mm/m²/day), vine water use from veraison to harvest was greater for vines on the deep cracking clay soil than for vines on the terra rossa soil, particularly after veraison.

Vines on the black cracking clay soil had more vigorous and longer shoots and higher pruning weights, had denser canopies and higher yields than vines on the terra rossa soil. Berry colour (mg anthocyanins/g berry weight) was higher for berries from vines on the terra rossa soil than for berries from vines on the black cracking clay soil. Wines from vines of the terra rossa soil had a more intense aroma — stronger blackcurrant character — and were more full-bodied, concentrated, balanced and complex than wines from vines on the black cracking clay soil (Figure 14.5).

Conclusions: The comparison demonstrates how terroir, and in this case predominantly soil characteristics, can impact on vine growth, berry characteristics and wine style and quality. The 'flavour shape' of each wine is shown in the bottom section of the web (Figure 14.5). Vines grown on the terra rossa soil were more suitable for the production of a rich, full-bodied dry red wine than the vines grown on the deep black cracking clay soil.

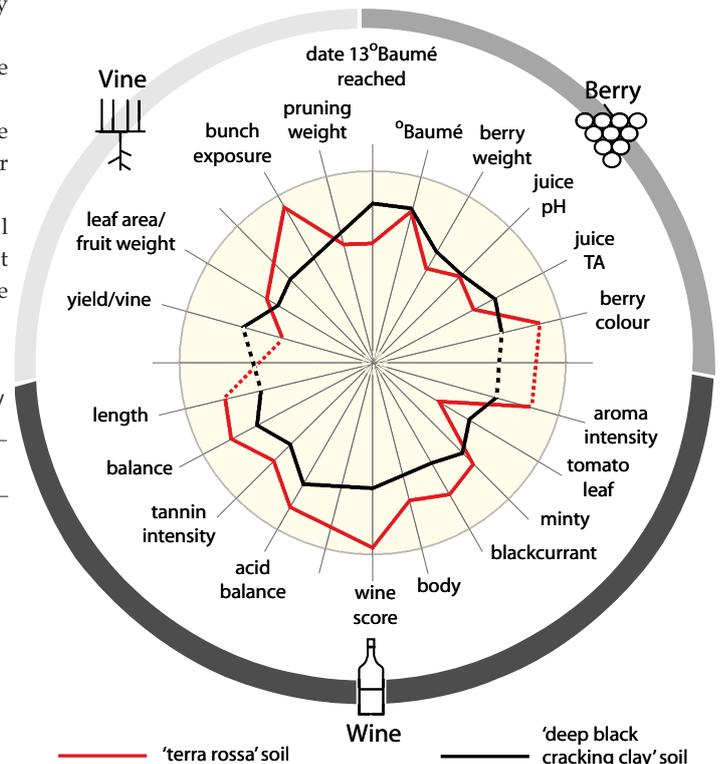


Figure 14.5 A 'vine to wine' web showing vine, berry and wine characteristics from terra rossa and deep black cracking clay soils.