Figure 1.32 (a) The 'terra rossa' soil and (b) the 'deep black cracking clay' soil (photographs P. Iland).

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/m^2/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 (data not shown). Wines from vines of the terra rossa soil had a more intense aroma — stronger blackcurrant character — and were more full-bodied,

Table 1.1 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

concentrated, balanced and complex than wines from vines on the black cracking clay soil.

The comparison is illustrated as a 'vine to wine' web diagram (Figure 1.33) that demonstrates the differences in vine, berry and wine characteristics between the two sites. In this case it is highly likely that the differences are largely driven by the difference in the soil components of the terroir of each site. 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.

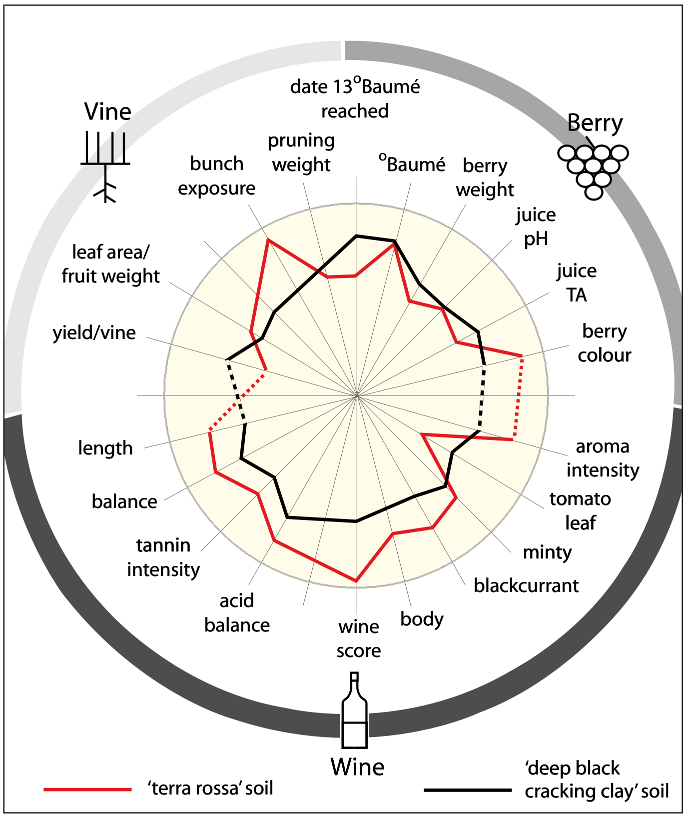

Figure 1.33 A 'vine to wine' web showing vine, berry and wine characteristics from terra rossa and deep black cracking clay soils (graphic G. Lavis).

1.15.5 THE GROWER'S ROLE

The grower may use a few or many techniques to manage their vines, e.g. canopy management, irrigation, nutrition, use of compost/mulches, etc (Chapters 10, 11 and 12). The following examples help to explain the link between terroir and the role of the grower.

Example 1.15

Allen Jenkins and Ben Harris (Wynns Coonawarra Estate, Coonawarra) (pers.comm.)

Elevation and soil profile can change across sections of a Coonawarra vineyard (Figure 1.34). The map shows the black cracking clay soils on the lower ground to the left, changing to the terra rossa across the ridge and to the sandy soils on the right of the ridge.

The terra rossa is mainly found on the higher elevated sites. Elevation between the terra rossa sites and the lower sites is in the order of only 2 metres. The terra rossa soils consistently produce more concentrated wines.

2.3.14 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 2.27). Bunch length, width and weight can vary widely depending on variety and cultural practices (Figure 2.34).

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.

Figure 2.34 Different sizes and weights of Cabernet Sauvignon bunches (photograph T. Proffitt).

When vines are mechanically harvested the berries are shaken off the rachis, which usually remains attached to the shoot (Figure 2.35). 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 2.35 The rachis after the vine has been mechanically harvested (photograph T. Proffitt).

BUNCH COMPACTNESS

Bunch compactness (tight or open bunches) refers the way that the berries are arranged on the rachis of the bunch in relation to the space of the bunch. This is important because compact bunches heat up more so than open bunches, are more susceptible to incidence of disease and pests and show less homogeneous ripening (Intrigliolo et al. 2014, Cubero et al. 2015, Tello et al. 2015, Tello and Ibanez 2018).

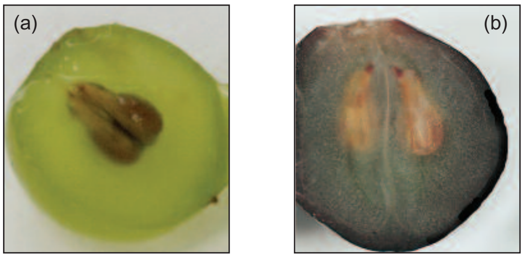

Figure 2.36 (a) A white and (b) a black grape berry cut into halves (photographs E. Wilkes).

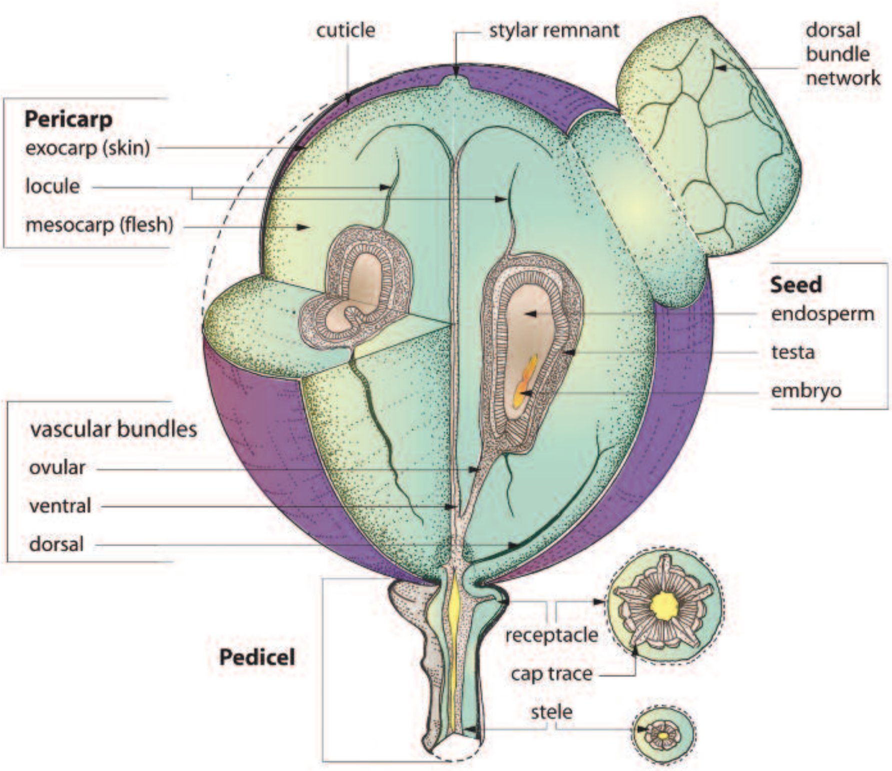

Figure 2.37 Structural components of the berry (adapted from a figure in Coombe 1987, used with permission from the American Society for Enology and Viticulture) (graphic G Lavis).

AN EXAMPLE OF AN INTEGRATED DISEASE AND PEST MANAGEMENT STRATEGY

An integrated disease and pest management strategy is the combination of some or all of the following methods — educational, physical, cultural, genetic, biological and chemical — to prevent/control diseases and pests.

PREVENTION

EDUCATIONAL
- Understand the weather patterns for a region.
- Educate staff of the life cycle of different diseases and pests.
- Train vineyard staff to recognise diseases and pests.
- Establish monitoring protocols.
- Establish treatments for common diseases and pests.
- Train/employ a dedicated monitoring person experienced in detecting and evaluating disease and pest incidence and severity.
- Identify hot spots in the vineyard for targeted monitoring.
- Make staff and visitors aware of biosecurity issues and protocols.
- Use apps to aid identification and assessment of diseases and pests.
- Place educational material, e.g. 'Vinehealth' posters in staff work places.

PHYSICAL
- Match varieties to a region, e.g. early maturing varieties for regions that typically have late summer rains.
- Use vine material with high health status from accredited supplier.
- Provide a barrier, e.g. fence/hedge to prevent visitors/animals from entering the vineyard.
- Establish and maintain protocols for 'Farm-gate hygiene'.
- Remove infected material, e.g. prunings from the vineyard.
- Vine shaking /mechanical crop thinning.
- Selective harvesting — hand pick infected fruit and discard prior to harvest for winemaking.
- Establish effective spray application.
- Apply remedial action in winery.

GENETIC
- Select varieties and rootstocks that have high natural resistance.
- Select varieties that have an open bunch structure and/or thicker berry skins.

CULTURAL
- Establish a moderately open/open canopy to allow air flow and efficient spray application to foliage and fruit. Degree of openness will depend on regional climatic conditions and targeted wine style.
- Maintain sound vineyard floor management practices, e.g. fix irrigation leaks to avoid ponding of water under vine/mid row; hollow areas also can be hot spots for water pooling/slash cover crop early if potential disease pressure, e.g. botrytis bunch rot, is high.

INTERVENTION

Monitoring techniques are a key part of an integrated disease and pest management strategy.

BIOLOGICAL
- Use natural sprays, e.g. oils, milk products and microbiological pathogens to control diseases.
- Follow manufacturer's recommendations for concentration and timing of spray.
- Establish natural vegetation to increase predator population to suppress undesirable pest population
- Release predators into vineyard.

CHEMICAL
- Initially select the least toxic option to control disease/pest.
- Follow manufacturer's recommendations for concentration and timing of spray.
- Follow regulatory guidelines for withholding periods.

Figure 9.54 The key components of an integrated disease and pest management strategy and some examples within each category

When vines are severely water-stressed, petioles may detach from the stem and some leaves may be lost. This survival mechanism may save the vine from loosing other leaves and it shoots (and buds), but results in the potential for berry shrivel. If berry shrivel is severe grape/wine quality may be compromised. But then, the vine did not evolve its survival mechanisms with any consideration of winemakers' needs; it is the seeds that the vine is concerned with for its survival.

(a) (b)

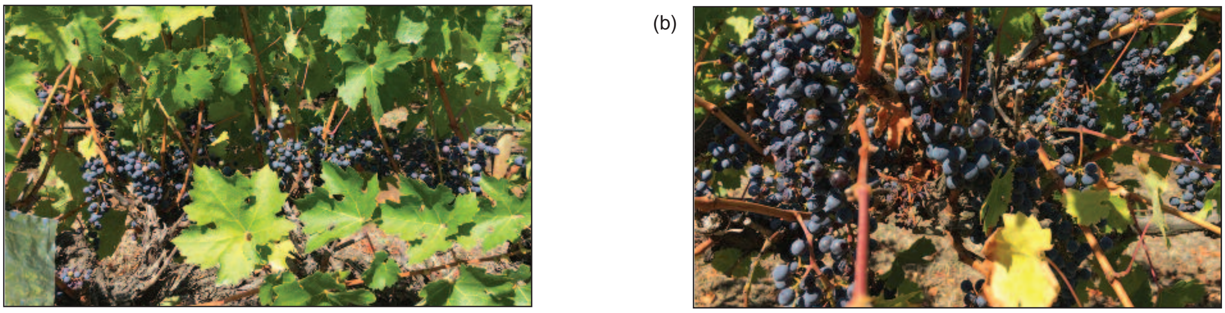

Figure 11.26 (a) Leaf loss and (b) the resultant berry shrivel from the exposure of bunches to high temperatures and higher solar radiation. than the pre-leaf loss conditions (photographs V. Pagay).

11A.6 From the theory to the practice – applying knowledge of leaf water potential and hydraulic conductance studies to vines in the vineyard

Interpreting the results of different experiments

It can be difficult to interpret the results of different experiments because they are carried out on either potted vines or in the field (vineyard), with different varieties, under different environmental conditions and irrigation amount and scheduling. Nevertheless, general guidelines can be provided.

A guide to values for the different measures of vine water potential and how they relate to the degree of water stress that the vine is likely to experience in the vineyard is presented in Figure 11.27.

A summary of the outcomes of different vine water stress levels (measured as stem water potential) as proposed by Gambetta et al. (2020) is presented in Figure 11.28.

The values in Figures 11.27 and 11.28 are helpful when planning irrigation strategies.

Note, values for the different indicators of vine water stress may vary slightly between different studies and views of different authors/irrigation scheduling operators.

Depending on the targeted wine style, irrigation scheduling (amount and timing) might be such that the vine is under some degree of stress at certain times during the growing season — a topic we discuss later in the chapter.

The goal of an irrigation strategy is to achieve a vine water potential that results in a vine architecture and function that achieves a berry composition suitable for a targeted wine style.

A vine water potential scale

	No Stress		Low Stress		Moderate Stress	High Stress	Extreme Stress
$\Psi_{PD,leaf}$ (MPa)	-0.05	-0.2	-0.4	-0.6	-0.8	-1.0	< -1.2
$\Psi_{MD,leaf}$ (MPa)	-0.1	-0.5	-0.9	-1.1	-1.4	-1.6	< -1.8
$\Psi_{MD,stem}$ (MPa)	-0.05	-0.3	-0.6	-0.8	-1.0	-1.2	< -1.5
g_s (mol m^{-2} s^{-1})	> 0.3	0.25	0.2	0.15	0.1	0.05	< 0.03

Figure 11.27 A guide to the values of leaf and stem water potential and stomatal conductance in relation to the level of water stress of grapevines (graphic V. Pagay).

Example 12.33

Yu et al. (2022)

This study examined several trellis systems in a warm region — Vertical shoot positioned (VSP), two modified VSP systems, a single high wire system (SH), a high quadrilateral system (HQ) and a Guyot pruned VSP (GY) combined with 25%, 50% and 100% ET_C water replacement.

Table 12.9 Yield/per vine and physical and chemical composition of berries of the VSP, SH and HQ trellis systems for vintage 2020.

Parameter	VSP	SH	HQ
Yield (kg/vine)	4.3a	4.7a	3.6b
Berry weight (g)	0.97a	0.86b	0.87b
Total soluble solids (°Brix)	23.5b	24.6a	24.1a
Total anthocyanins (mg/g berry fresh weight)	1.35b	2.06a	1.61b

The Single high wire (SH), the High quadrilateral system and (HQ) systems provided a more favourable bunch exposure environment and overall vine performance than the Vertical shoot positioned system (VSP) system (Table 12.9). The SH system provided an equal yield to the VSP and with a higher berry anthocyanin content and concentration.

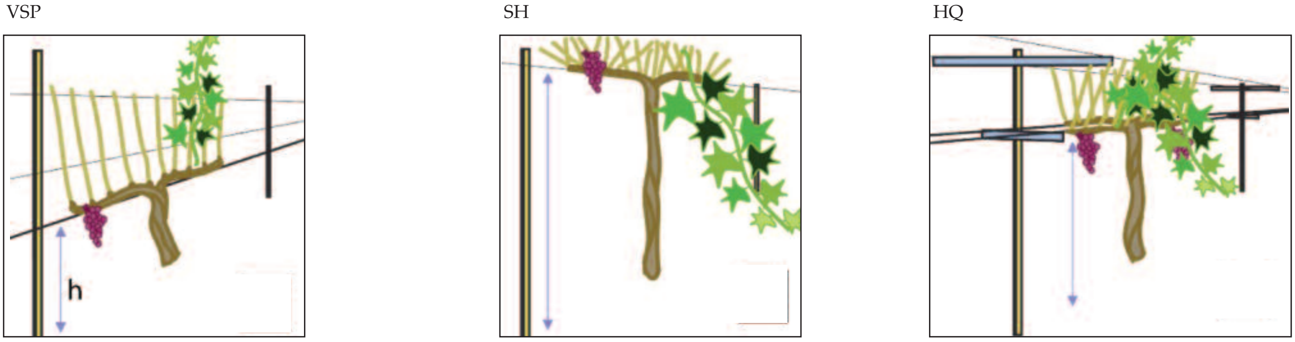

Figure 12.21 Diagrams of the canopy systems investigated by Yu et al. (2022). From Yu, R., Torres, N., Kacur, S.M., Marigliano, L.E., Zumkeller, M., Gilmer, J.C., Gambetta, G.A. and Kurtural, S.K. (2022) Adapting wine grape production to climate change through canopy architecture manipulation and irrigation in warm climates. Frontiers in Plant Science October 2022. doi.org/10.3389/fpls.2022.1015574. Copyright the authors. (graphics supplied by K. Kurtural). Used with permission.

Figure 12.22 Photographs of the SH trellis canopy investigated by Yu et al. (2022). From Yu, R., Torres, N., Kacur, S.M., Marigliano, L.E., Zumkeller, M., Gilmer, J.C., Gambetta, G.A. and Kurtural, S.K. (2022) Adapting wine grape production to climate change through canopy architecture manipulation and irrigation in warm climates. Frontiers in Plant Science October 2022. doi.org/10.3389/fpls.2022.1015574. Copyright the authors. Photographs provided by K. Kurtural.

12.13 Sprinkler cooling systems

Another means to reduce temperature within grapevine canopies is to use evaporative cooling systems. Sprinkling/misting water, either with above or with-in canopy water sprinkler systems, has been successful in lowering the air temperature inside grapevine canopies. The cooling effect is due to the combined effect of evaporative cooling and the lower temperature of the water delivered into the canopy (Caravia et al. 2017).

12.13.1 Above canopy sprinkler systems

Example 12.34

Alijbury et al. (1975), Kliewer and Schultz (1973)

Alijbury et al. (1975) — Operation of an overhead sprinkler system when air temperature reached above 32°C in Chardonnay, Riesling and Chenin Blanc vineyards resulted in a decrease in canopy temperature usually in the range of 5-10°C. Berries of 'sprinkled' vines were larger, had lower juice °Brix and had little difference in acidity parameters. Similar results were obtained for potted vines (Kliewer and Schultz 1973).

Figure 12.25 A heat damaged leaf (photograph T. Proffitt).

Figure 12.26 Sunburnt berries (photograph T. Proffitt).

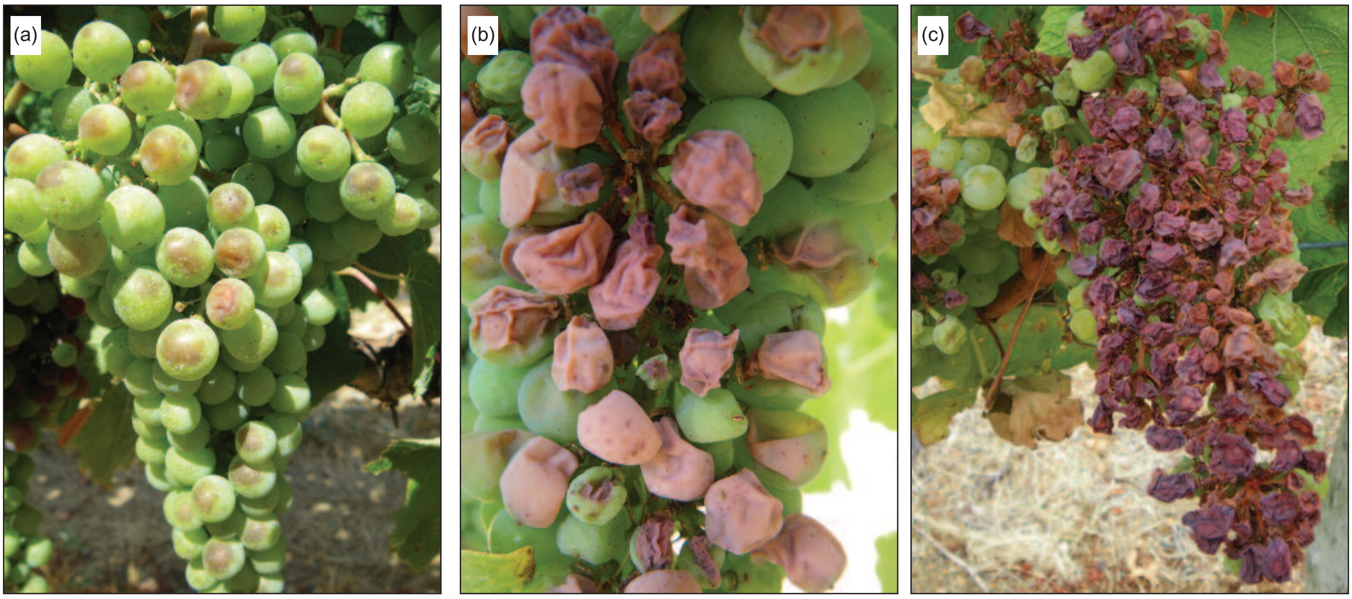

Figure 12.27 Heat damaged berries on (a) the day, (b) one day after and (c) one week after a heatwave event (photographs T. Proffitt).

12.16 Sun protection agents

12.16.1 heatwaves

Products known as 'sun-protection' agents applied as foliar/bunch sprays may be useful to protect leaves and bunches from high temperature/high solar radiation damage (Dry 2009, Dry et al. 2009, Scarlett 2009 and references in the examples that follow).

Information on spray characteristics is sourced from Brillante et al. (2016), Gatti et al. (2016), Rogiers et al. (2020), company product information sheets and industry contacts.

These sprays are used for various purposes:
- to minimise water usage (particularly in hot or drought conditions);
- avoid vine stress;
- lower leaf and berry temperature;
- protect berries from sunburn;
- to reduce berry sugar concentration (°Brix) and
- for disease/pest control.

Usually the spray is applied over the whole canopy but can also target the bunch zone. The aim is to minimise vine water stress and/or to protect berries from heat damage without, or only to a small degree, altering berry physical and biochemical processes.

Berry composition/wine composition and wine sensory attributes may be affected by application of the spray — a topic discussed in the various examples in this section.

There are several products available. Commonly used sprays are based on pinolene, kaolin, calcium carbonate crystals or chitosan.

Before using these products you should check the regulations — permitted use and withholding period prior to harvest — of the country of origin, the country of intended wine export, and, the wine company that is purchasing the grapes.

Recommendations from product suppliers should also be considered — preparation of sprays, concentration and timing of sprays and spraying conditions (e.g. do not spray if ambient temperature is high, e.g. >27°C).