FACT SHEET

SEPTEMBER 2012

GRAPEVINE BIOLOGY

Mary Retallack - *Retallack Viticulture*

The following topics are covered in this Fact Sheet:

- The main types of plant tissues (meristematic, dermal, photosynthetic, structural and vascular);
- Grapevine anatomy (roots, shoots, buds, leaves, flowering, fruit);
- Photosynthesis, translocation, transpiration, respiration.

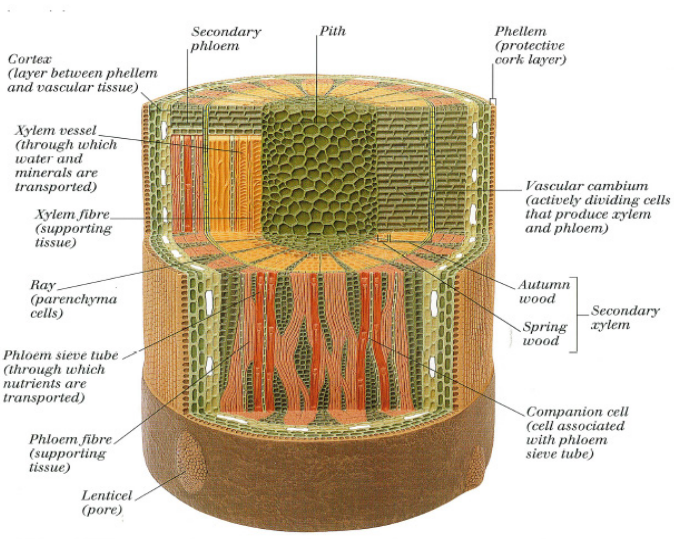
This is followed by a detailed section outlining how these aspects relate to vineyard management.

Cell Structure and Function

Types of plant tissues

Growth (meristematic) tissue

Meristematic cells divide to make more cells, allowing the vine to grow. They occur in the buds, root tips and shoot tips (development of organs). The cambium layer of the vine shoot/cane is an example of a secondary meristem because it enables organs to grow in thickness.



Protection (dermal) cells

The cells of the epidermis are the outermost layer of cells on all plants. The bark protects the inner cells from physical damage.

Photosynthetic tissue

Chloroplasts are sugar producing cells which are mainly found in the leaves. The chlorophyll in them enables photosynthesis to occur.

Support tissue which makes up the cortex

Collenchyma (living outer most layer) cells; form a complete cylinder around the stem. They are elongated and have thicker cell walls due to additional cellulose, deposited within their walls.

Sclerenchyma (support) cells; are similar to collenchyma cells but have additional lignin fibres in their cell walls. As these fibres mature and die they leave a hard skeleton of lignin fibres.

Parenchyma (storage) cells; are living cells which have large central vacuoles (storage vessels) and thin but flexible cell walls. They form the cortex and pith of stems, the cortex of roots and the mesophyll of leaves.

Vascular or conducting tissue

Xylem

Xylem tissue conducts water and dissolved mineral salts. Perforations in cell walls facilitate the movement of water and dissolved substances from the roots upwards into the shoot system of the vine.

Phloem

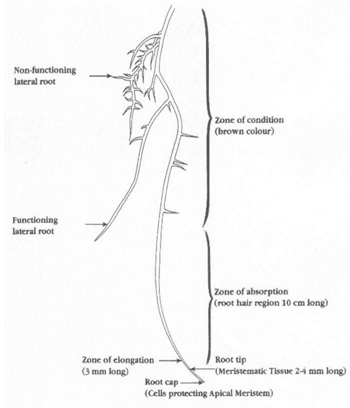
Phloem is the food or sugar conducting tissue located on the inside of the bark. Sugars are moved from the production site to a 'sink' or where it is to be utilised.

Root Distribution and Function

Primary growth

Young roots contain a root tip which is a region of rapidly dividing cells protected by a root cap. Behind this is the area of absorption of nutrients. The root apical meristem allows for extension growth. As the root develops, the epidermis dies and is replaced by the exodermis. This gives the root the brown colour.

Concentrically from the outside a root is formed by the epidermis, followed by the cortex (parenchyma cells), and the endodermis which contains the Casparian strip, a layer of cells with thickened cell walls that regulate solute transport (helping to protect vines from effects of soil toxicities).



1) ***Anchorage***
Many new roots grow each year, some of which develop into main structural roots that support or anchor the vine. Most of the annual root growth dies in the same season.

2) ***Water and nutrient absorption***
Dissolved nutrients in the soil solution are absorbed by feeder roots and diffuse into the vascular tissue (the xylem).

3) ***Storage of reserves***
In late summer and autumn, some of the products of leaf photosynthesis (sugars) are transferred via the phloem tissue back to the root system and other woody parts of the vine providing carbohydrate reserves for the next season's growth.

4) ***Hormone production***
Hormone production (gibberellin/cytokinin) by the roots influences growth and development of the shoots and clusters of the grapevine.

The Shoot

A shoot is the succulent stem bearing the leaves, tendrils and flower clusters (inflorescences).

All of the information required to grow a shoot is contained within a bud. Growth in length occurs via cell division at the shoot tip (in meristematic tissue) and by elongation of the newly formed cells.

Leaf function

In the developing grapevine, the leaves undergo a gradual transition from importing photosynthetic products to export.

When the leaf is 1/3 its full size it exports more food than it uses and begins to contribute to vine growth. When the leaf reaches its full size (about 30 to 40 days after unfolding) it is photosynthesising at its peak.

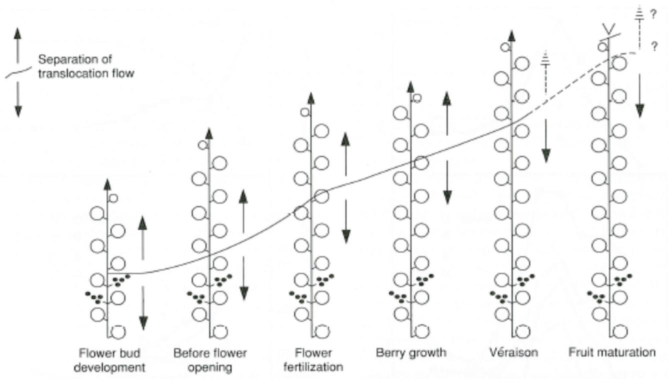


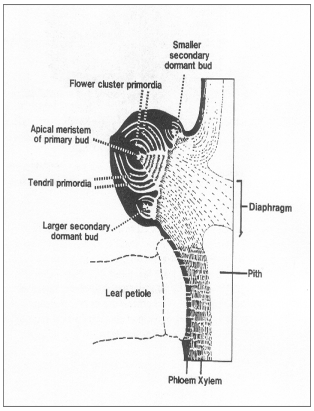
Figure 3.20 Development in the translocation of photosynthate from leaves during shoot growth. (After Koblet, 1969, reproduced by permission.)

Following harvest/fruit removal, the majority of photosynthates are directed towards and stored in the roots. Leaf fall or senescence normally begins in late autumn when minerals are translocated (remobilised) back into the canes and trunk.

Buds

Buds may be classified into either a 'prompt' bud or a 'compound' bud.

The compound bud



The compound bud is comprised of the primary, secondary and tertiary latent buds. Each bud contains three partially developed shoots enclosed in small leaf like structures called bracts which develop in the leaf axil.

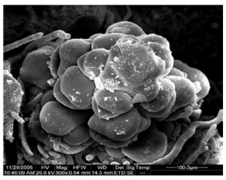
The Lateral Shoot and Prompt Bud

The summer lateral grows from a prompt bud in the leaf axil. It produces shoots and leaves in the current growing season and is usually not fruitful. Compound buds produce shoots, leaves and fruit after the completion of winter dormancy.

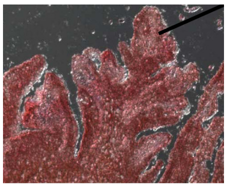
Formation of Grapevine Flowers

1. ***Anlagen;*** First anlagen form as club-shaped meristematic protuberances from the apices of latent buds. At this stage, the anlagen are uncommitted primordia; they may develop into inflorescence primordia, tendril primordia or shoot primordia.

Inflorescence primordia sampled in May 2006



Inflorescence primordia sampled in August 2006



Inflorescence primordia

2. ***Inflorescence primordia;*** The formation of inflorescence primordia takes place if the anlage undergoes repeated branching to develop many rounded branch primordia. This process is controlled by both environmental (temperature, light) and endogenous (growth regulator) factors.

3. ***Flower formation;*** Grapevine flowers are small (4-5 mm) and grouped together in a flower cluster or inflorescence.
The inflorescences occur opposite a leaf in the same position as a tendril (there are several hundred flowers per inflorescence).
Six to ten weeks after bud burst, flowering takes place.

Poor Set

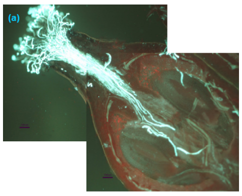
Poor set may be characterised as Coulure, Millerendage and/or 'Hen and Chicken'.

1) ***Coulure*** occurs when many flowers fail to develop into berries and drop (shatter) from the cluster within 10 days of opening.

2) ***Millerendage*** is a condition characterised by berries arrested at different stages of development and of different berry sizes on the same bunch.
They may include but are not limited to live green ovaries (LGOs), chickens or a combination of both (resulting in a loose bunch).

3) ***Hen and Chicken*** is a condition where there are a high proportion of small, coloured and unfertilised 'chicken' berries on a bunch.

Factors Affecting Berry-Set



Berry set is reduced by high temperatures during and immediately after flowering. Water stress at flowering and during the subsequent four weeks has been associated with poor set.

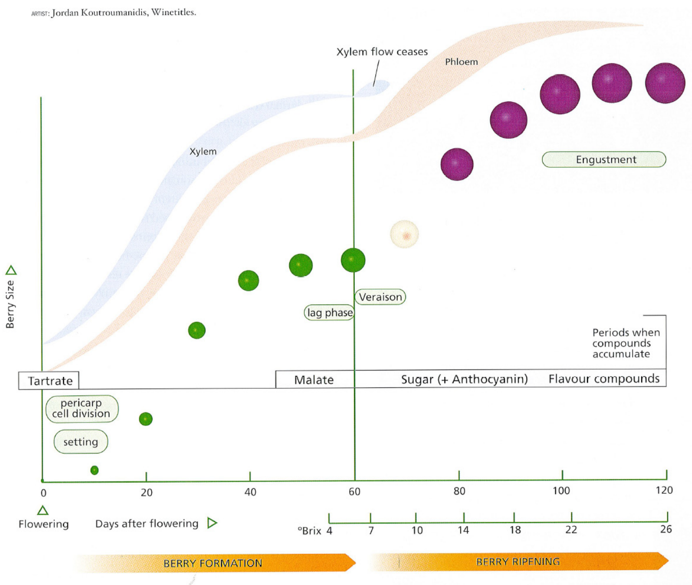
Berry growth stages

***Stage 1:* Rapid Growth (40 to 60 days)**

The seed increases in size. There is a rapid increase in berry size due to cell division in the first two weeks, and some expansion; the berry remains hard, acid is high and sugar levels almost constant.

***Stage 2:* A lag stage of nil or slow growth (7 to 40 days)**

The 'lag phase' is a period when either less growth or no growth in volume occurs. The boundary between stage 2 and 3 is often unclear.



***Stage 3:* Growth resumes and maturation begins (approx 35 to 55 days)**

The onset of Stage 3 is signalled by veraison, the point of sudden change in colour. During this stage, the berry softens, acid levels decrease, sugar is accumulated, varietal flavours and aromas develop. The rapid increase in berry volume is due to cell enlargement.

Photosynthesis

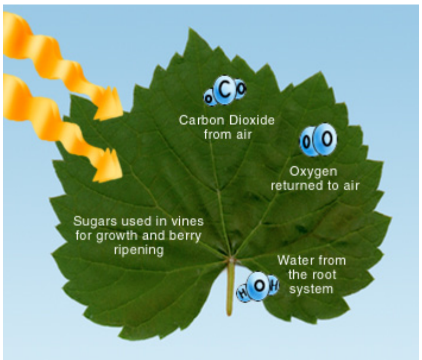
Water and carbon dioxide are combined in the chloroplasts to produce sugars and starch using light energy. The water used in photosynthesis is absorbed from the soil by the vine roots. The carbon dioxide is obtained directly from the air and enters the leaves via the stomata.

$6H_2O + 6CO_2$ + light energy (in the presence of chlorophyll) > $C_6H_{12}O_6 + 6O_2$

Six molecules of water plus six molecules of carbon dioxide produce one molecule of sugar plus six molecules of oxygen.

The photosynthetic parts of plants can usually be recognised by their green colour due to the presence of chloroplasts. This pigment is capable of absorbing energy from sunlight and utilises carbon dioxide and water from within the cell to produce sugar with oxygen as a waste product. Photosynthesis involves many steps and is controlled by the action of selected enzymes. The resulting sugars are basic building blocks of most chemical materials found in the grapevine. These sugars are used in respiration.

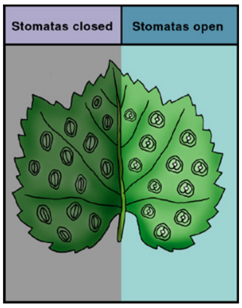
What Affects the Rate of Photosynthesis



The photosynthesis rate of grape vines is influenced by factors of the environment and by various characteristics of the vine.

These factors include:

- **Light;** Light intensity, quality (wavelengths) and duration. A single leaf in direct sunlight will absorb about 90% of the sun's radiation. Stomata open and close in relation to sunlight. They are fully open at PAR of about 200µEm-2S-1. In grapevines no photosynthesis occurs at low light levels, below about 30µEm-2S-1 (about 1.5% of full sunlight). As light intensity increases so does photosynthesis until about ⅓full sunlight is reached or 700 µEm-2S-1. At this intensity photosynthesis in grapevines is termed 'light saturated' and remains at about the same rate with even higher sunlight levels.
- **Temperature;** The ideal temperature for photosynthesis is generally between 20 and 30°C (and optimally at about 24°C). Below 10°C there is little photosynthesis and it declines rapidly above 35°C.
- **Water Status;** Water affects the opening and closing of the stomata and thus the entry of carbon dioxide into the leaves. When the vine's water supply is limited there is a rapid decline in photosynthesis. The amount of water available for photosynthesis is determined by, the rate of transpiration, humidity, mineral availability, and stomata opening.



- **Leaf Age** – The rate of photosynthesis increases rapidly in a young grapevine leaf during the period of rapid leaf expansion as it gets older and loses its colour the rate of photosynthesis declines.

Translocation

Translocation is the process by which chemical materials and nutrients are moved throughout the vine. Stored foods flow in the phloem from the leaves to other parts of the vine.

Transpiration

Water absorbed by the roots is drawn into the leaves from where it evaporates in a process known as transpiration. The green parts of the grapevine evaporate large amounts of water during the growing season.

The grapevine can control the rate of moisture loss (transpiration) via the stomata. The stomata open in the day and close at night. Under some conditions, they may also close during the day particularly on a hot, windy afternoon.

Factors Affecting Transpiration

The most important environmental factors affecting transpiration are:

- **Humidity;** Transpiration decreases as the humidity surrounding the leaves increases. As the vapour in the air increases, this slows down the water loss through the stomates.
- **Temperature;** A rise in leaf temperature will increase transpiration. Sunlight on a leaf causes the temperature of the leaf to become warmer than the surrounding air. The vapour pressure (conversion of a liquid to a gaseous form) inside the leaf will then be higher than the surrounding air resulting in increased water loss as the two pressures attempt to equalise.
- **Light Intensity;** The temperature of the leaf is increased as the light intensity increases and this increases the rate of transpiration. The light level determines whether the stomates are open or closed.
- **Wind;** The wind movement over the leaf takes with it the layer of water vapour accumulated near the surface. This increases the rate of transpiration. Winds of 11 to 14km/hr are sufficient to cause the closure of stomates (reducing photosynthesis and transpiration).
- **Water content of the soil;** Transpiration is influenced by both the water content of the soil and the rate at which roots can absorb water. During daylight, water is often transpired at a greater rate than it is absorbed from the soil. At night, this situation is reversed.

Respiration

Plants require an internal source of energy to grow and manufacture complex chemical molecules. This chemical energy is produced by respiration where sugars (from photosynthesis) and oxygen along with other compounds interact and produce energy along with water and CO2. During respiration, the energy stored by the vine is released.

$$C_6H_{12}O_6 + 6O_2 > 6CO_2 + 6H_2O + \text{Energy}$$

Glucose + Oxygen (in the presence of many enzymes) **is converted to Carbon Dioxide + Water + Energy**

Comparison between photosynthesis and respiration

The process of photosynthesis and respiration may appear but are not the reverse of each other. The series of enzymes used in each process is different and the order of reactions is not the reverse of each other.

Photosynthesis and respiration occur at the same time and are interdependent

In photosynthesis, energy is stored and in respiration, energy is released

References

Collins, C. (2004) Flowering and Fruit set of the Grapevine, Final Report to GWRDC, UA 04/02

Coombe, B.G. (2001) Ripening Berries – a critical issue. Australian Viticulture, March/April, p28 – 34.

Coombe, B.G and Iland, P.G. (2004) Grape Berry Development and Winegrape Quality, in Dry, P.R., and Coombe, B.G., EDs. Viticulture – Volume 1 Resources. Winetitles, Adelaide

Dry, P.R. (2008) Measurement and Terminology, the importance of getting it right. AWITC presentation

Flaherty, D.L. (Ed) (1992) Grape Pest Management. University of California, Davis.

Gibbard, M.R., Ellery, A.J., and Henry, J.S. (2003) Grapevine Research in Functional Plant Biology, Continuing Australian Journal of Plant Physiology, Vol 30, 6

Heazelwood, J. (2008) Inflorescence Initiation and Floral Differentiation in Vitis Vinifera L. Pinot Noir, AWITC presentation

Jackson, R.S. (1994) Wine Science, Principles and Applications, Academic Press, San Diego.

Lindsay, M. (Ed). (1992) The Visual Dictionary of Plants, Dorling Kindersley Limited, London.

May, P. (2004) Flowering and Fruitset in Grapevines. Lythrum Press, Adelaide

Pongracz D P. (1978) Practical Viticulture, David Philip Publishers, Cape Town, 23, 25

Murray Valley Winegrowers' Inc

retallack viticulture
wine growing for the future

gwrdc regional
grassroots solutions

VINEYARD MANAGEMENT CONSIDERATIONS

Impacts on vine health due to drought conditions

Drought Related Issue	*Impact on Vine Biology*	*Vineyard Management Considerations*
Lack of early season soil moisture (the soil profile is not full at the end of winter)	Significant reduction in vine vigour and fruit set is likely if vines are stressed at the start of the growing season.	Monitor soil moisture during winter months and in the lead up to budburst. Apply an early season irrigation to ensure the soil profile is full from budburst if required.
Less water available **Less water in storage and allocations of irrigation water may be reduced**	Reduced water availability may result in vine stress early in the growing season (see above). Careful timing and use of available irrigation water is critical to vine health. Do not grow a large canopy if you do not have the water to ripen a large crop or maintain the additional shoot area.	Develop an irrigation budget and determine if additional water needs to be purchased (if available and cost benefit warrants additional purchase). Monitor vine growth carefully ensuring irrigation is applied at key times without encouraging excessive shoot length.
Salinity **Irrigating with saline water (or where soil salinity is high).**	All irrigation water contains dissolved salts at some concentration, as water is transpired by the vine these salts are left behind in the soil. If saline irrigation water is applied this is another source of salt entering the soil. Depending on level of water salinity and the build up of salts in the root zone, this may reduce vine vigour and adversely impact on vine health and fruit quality. If replanting your vineyard consider planting onto salt resistant rootstocks.	Consider applying an additional leaching irrigation in winter following a rainfall event and apply regular irrigations during the growing season to push the salts outside the root zone. Minimise the use of fertilisers which may add to the 'salt load' in the root zone (some nutrients may be needed to encourage vine vigour and maintain vine health). Mound undervine to provide a larger area for roots to explore (above an existing water table) and apply mulch undervine to minimise water loss.
Wind **Often more wind with greater evaporation**	Stomata will close frequently in windy conditions (winds of 11 to 14 km/hr are sufficient to cause the closure of stomata). This will reduce the level of transpiration and limit the production of photosynthates. Prolonged exposure to windy conditions may result in poor vine growth.	Install windbreaks; apply undervine mulch to maintain soil moisture.
Frost **Intensity of frost events may be higher due to dry soils.**	Frost can cause severe damage to emerging shoots and even dormant buds. If the primary bud (or shoot) is damaged the secondary shoot may grow to takes its place (the fruitfulness is likely to be lower).	Frost mitigation strategies include, moist soil surface, vegetation slashed, frost fans, overhead sprinklers, use of tiny tags to monitor temperature. You may find buds burst from undesirable positions and they will need to be removed either shoot thinning during the growing season or at pruning time.
Carbohydrate reserves **Vine's stored carbohydrate (sugars and starch) reserves are lower**	Grapevines rely on stored carbohydrate reserves early in the season for root and shoot growth (until leaves are 1/3rd full size and can contribute to the vines energy requirements). Low vine carbohydrate reserves will impact on vine vigour and capacity to grow fruit.	Avoid significant vine stress as this will reduce the vine photosynthesis (and carbohydrate production). Maintain the functioning leaf area post-harvest so the vines can produce and store carbohydrate reserves (this is particularly important for higher yielding varieties). Apply sufficient water and fertiliser early in the season to assist the vines in replenishing carbohydrate reserves early in the growing season
***Vine Issue** (related to drought)*	***Impact on Vine Biology***	***Vineyard Management Considerations***
Poor root distribution	Vine roots are usually concentrated in the top metre of soil directly under the vine canopy. Wide dripper spacings may create 'silos' of alternating wet and dry areas resulting in the root area being naturally 'pruned'. Vine roots produce a plant hormone called abscisic acid (ABA) in response to stress. This signals the vine to 'shut down' until conditions improve.	Install drippers with closer emitter spacings or install additional drippers to maintain a wetted 'strip' undervine. This will encourage greater root exploration (mulch to retain water for longer).
Short shoots **Fewer functional leaves to ripen the crop.**	The potential for an unbalanced (over cropped) vine resulting in longer term vine health issues and poor fruit quality.	Apply irrigation to grow sufficient shoot area to ripen crop. If the shoot length (or leaf function) is reduced then reduce the crop load accordingly.
Flowering may occur earlier than in a normal year	Frost, dry and windy conditions during flowering are not conducive for optimal set. High and/or prolonged low temperatures can also reduce set.	Ensure vines are not moisture stressed up to and during flowering. Be ready to apply pre-flowering nutritional sprays at optimal timing (Boron, Zinc etc).
Vine canopy stress **Ongoing stress may result in significant basal leaf loss**	Basal leaf defoliation will reduce the photosynthetic capacity of the vines (if the basal leaves are still functioning). Lack of fruit protection may result in uneven ripening, lower fruit quality (sunburn, phenolics characters, berry shrivel) and lower yield.	If hot weather is forecast start irrigating several days prior (preferably at night) to minimise vine stress. Maintain irrigation application throughout hot period (monitor how deep the irrigation is going down the profile).
Management Issue	***Impact on Vine Biology***	***Vineyard Management Considerations***
Vineyard re-development **Wind and site limitations**	Match variety (and clone) to realise the full potential of the site (soil, topography, aspect). Some vineyard sites are particularly windy and vines will struggle to grow well. Soil type may also be limiting.	Carry out a thorough site assessment prior to planting. Plant vines parallel to the prevailing wind and/or install a suitable windbreak to protect the vines. Consider alternative drought tolerant varieties?
Root distribution and health	Root distribution and health will be reduced in dry conditions, shallow root zones, nematodes, waterlogged environments (lack of aeration), impervious soil layers etc. will adversely impact on vine health.	Manage the soil environment for optimal root growth (encourage roots to explore the soil profile, deep rip hard pans, apply mulch to maintain soil moisture and reduce surface heat/reflection).
Nutrient application **Application of fertiliser**	Vines appear to have one main peak of root growth coinciding 4 to 6 weeks after budburst (near flowering). Ensure mobile fertiliser (nitrate) is applied when feeder roots are present to access them.	Consider the best way to apply fertiliser. Some nutrients are highly mobile and some are less immobile, this will affect the method of application. Some foliar nutrients need to be applied at key times (during spring and/or pre-flowering).
High temperatures	Grape berries exposed to bright sunlight on calm days can be warmed up to 15°C above the air temperature. Wind cools because it removes some of the stored heat from the surface of the berry.	Vines with sufficient leaf area to provide protection, a deep root system tends to cope with heat better than weak vines with poor vigour. Recovery from heat stress is rapid (2 to 5 days) if tissue damage is avoided.
Post harvest care **Getting ready for the next growing season**	Vines will export nutrients with the fruit produced. It is important to maintain vine health and build up the vines carbohydrate reserves prior to senescence. Vines will continue to function normally while actively functioning leaves are present.	Maintain irrigating until leaf senescence (while there are functioning leaves the vine will produce carbohydrates). Apply post harvest fertiliser if functional leaves are present to replace nutrients removed at harvest. Do not encourage new shoot growth.