FACTSHEET
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Post-harvest care of grapevines: Irrigation and nutrition

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Temperatures in most Australian grape-growing regions are warm enough for vines to retain their leaves for a period of time after harvest. In cooler areas, this may only be for a few weeks, but more commonly it extends from 1 to 4 months in the hotter, inland regions.

Continued photosynthesis and nutrient uptake during the post-harvest period allow vines to store carbohydrate and nutrient reserves for use in the next season. The aim of this factsheet is to describe the roles that carbohydrate and nutrient reserves play in the seasonal growth cycle of grapevines, and to discuss how irrigation and fertiliser inputs can be used most efficiently to promote carbohydrate and nutrient storage during the latter part of the season.

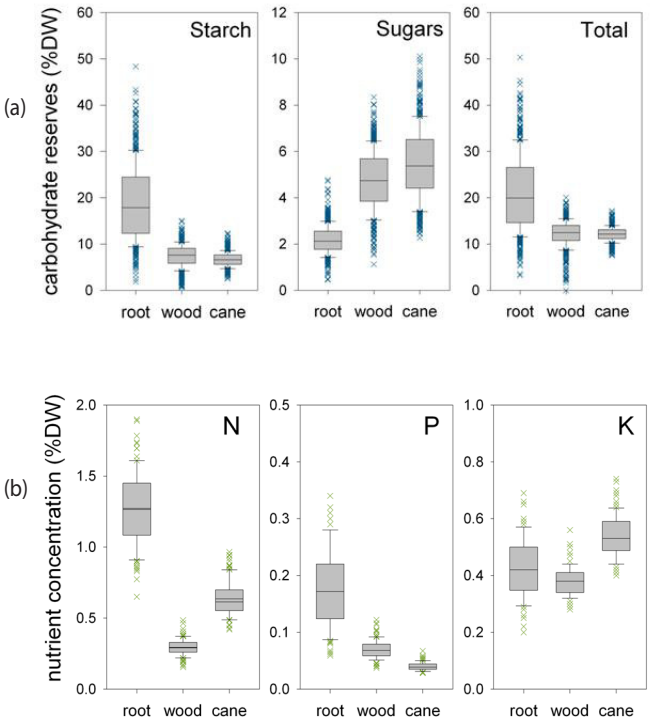


Figure 1: Concentration ranges of carbohydrate reserves (a) and macronutrients N, P and K (b) in grapevine root, wood and cane tissue at dormancy. Figures based on a survey of 34 own-rooted and grafted Shiraz and Chardonnay blocks across southern NSW over three consecutive seasons (Smith et al. 2009; Smith, Quirk & Holzapfel unpublished)

Carbohydrate reserve storage and dynamics

In spring, grapevines use carbohydrates from stored reserves in perennial tissues to support new root and shoot growth. These carbohydrates are stored as starch and as free sugars, mainly glucose, fructose and sucrose. The combined concentrations of starch and sugars in the roots range from approximately 3 to 50% on a dry weight (DW) basis, and in the wood from 2 to 20% DW (Figure 1a). Starch is stored as granules within the xylem and phloem ray cells, and areas of high starch concentrations can be seen at the whole-tissue level after staining with iodine (Figure 2). During the growing season, starch concentrations are higher than those of sugar in the wood, but leading into dormancy some starch is converted to sugar to help protect the vine from cold damage during winter. In roots, starch is the main form of storage carbohydrate all year round.

The total amount of carbohydrate reserves stored by dormant grapevines ranges between 0.52 and 2.2 kg/vine, with a typical single-cordon vine storing between 50 and 75% of its total reserves in the root system. Research suggests that more than 80% of these reserves can be used if needed, but normally less than half of the total stored carbohydrates are mobilised in spring. The difference provides vines with some buffering capacity to grow new shoots or leaves after events such as frost

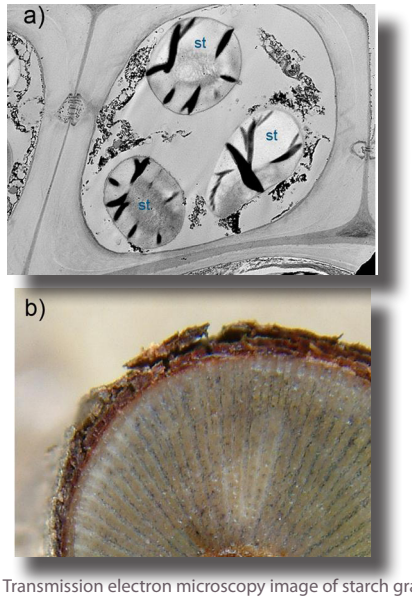


Figure 2: (a) Transmission electron microscopy image of starch granules (st) in a xylem ray cell of a dormant grapevine cane, and (b) a 2-year-old wood section at dormancy, showing areas of high starch storage in the xylem rays after the starch granules have been stained blue with iodine. [Images courtesy Helen Waite (top), Jason Smith (bottom)]

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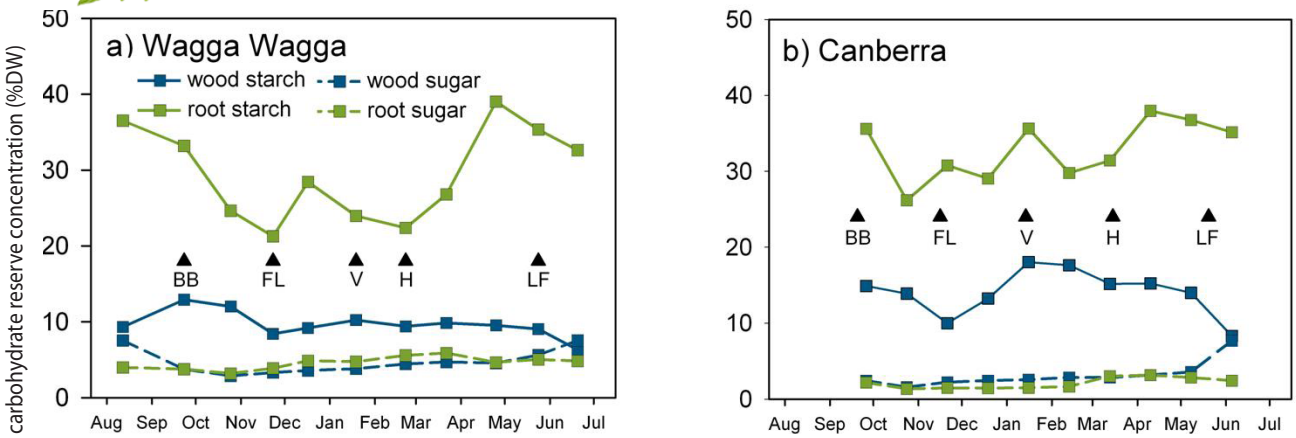


Figure 3: Seasonal pattern of carbohydrate reserve dynamics in the wood and roots of mature own-rooted Shiraz vineyards at two locations during the 2006/07 season. Growth stage dates are shown for bud-break (BB), flowering (FL), veraison (V), harvest (HF) and leaf-fall (LF). The yield and pruning weight ratio were (a) 13 t/ha and 4.6 respectively for the Wagga Wagga vineyard, and (b) 6 t/ha and 2.2 for the Canberra vineyard (adapted from Holzapfel et al. 2010).

or hail. Localised carbohydrate reserves are used to support initial shoot growth. In the weeks after bud-break, carbohydrate reserves from more distant parts of the vine are progressively utilised as vascular connections develop between the new shoot and mature wood from the previous season. Transport of reserve carbohydrates to the shoot reaches a maximum at the 8- to 10-leaf stage, and then declines as canopy photosynthesis becomes sufficient to meet carbohydrate demand. Newly produced carbohydrates then start to be exported back to the perennial parts of the vine. Below the ground, root growth flushes that occur in early spring are supplied from carbohydrates stored in the permanent roots.



Figure 4: Carbohydrate reserves are used to support initial shoot growth in grapevines

The high initial dependence on stored carbohydrates leads to a decline of starch concentrations in root and wood tissue through bud-break and into early spring (Figure 3). In the week or two leading up to flowering, the canopy begins to produce sufficient carbohydrates to replenish wood and root reserves. These stores continue to build in parallel with fruit ripening, provided that yields are sufficiently low, or photosynthesis rates high enough to produce excess carbohydrates. However, under high crop loads, conditions of vine stress such as water deficit or high temperatures where photosynthesis is reduced may cause reserve replenishment to be delayed. Under heavy crop loads, mobilisation of carbohydrates may also occur in the earlier part of the ripening period to aid berry ripening. In these situations, the post-harvest period is of particular importance for carbohydrate storage and to ensure long-term vineyard productivity

Nutrient reserves

As early nutrient demand in spring cannot be met by root uptake alone, storage of nutrient reserves prior to dormancy is also required to support shoot growth in the following season. The cycling of nutrients, and thus the vine's ability to store them and remobilise them again in spring, depends on nutrient mobility within the plant. This is high for the macronutrients nitrogen (N), phosphorus (P), potassium (K), sulphur (S) and magnesium (Mg), but low for calcium (Ca). With the exception of manganese (Mn), which also has low mobility, the micronutrients iron (Fe), zinc (Zn), copper (Cu), molybdenum (Mo) and boron (B) have intermediate mobility.



Figure 5: Leaf senescence after harvest. The post-harvest period is a critical time for carbohydrate storage in grapevines

Studies with whole mature vines have shown that about 50% of N and P in the new season's canopy comes from stored reserves. Around 15% of the demand for K is met by reserves, and 5% of that for Mg and Ca. Of the main macronutrient reserves, N is stored in the highest concentrations, followed by K and P (Figure 1b). Average Mg concentrations in the roots and wood are similar to those of P, and Ca is found in approximately the same concentration as K. There is little published information regarding the storage of micronutrients by grapevines.

Total N storage at dormancy ranges from approximately 25 to 70 g/vine, and like carbohydrate reserves, more than half will usually be found in the root system. For P, which is the other main nutrient reserve (in terms of the proportion of total reserves mobilised at bud-break), stored amounts range from 2.5 to 4.5 g/vine. For the other macronutrients, dormant vines store 10–25 g of K, 4–8 g of Mg, and 25–40 g of Ca. In warm climates, approximately one third of annual N and P requirements are met by post-harvest storage from the preceding season, 20% for Mg and Ca, and 15% for K. Storage of nutrients during the post-harvest period is due to both re-translocation from the leaves, particularly for N and P, and further root uptake from the soil.

Grapevine root growth style

Fine roots are important for the uptake of nutrients and water (Figure 5), and the peak of fine root growth can generally be expected between flowering and veraison in Mediterranean and cool temperate climates (Comas et al. 2010). In hot irrigated regions of Australia (e.g. the Murray Darling Basin), recent studies indicate that fine root growth can commence at or before bud-break in some seasons, with new roots present to some extent from spring through to mid-summer (EJ Edwards, personal communication; Smith & Holzapfel, unpublished data).



Figure 5: Soil pit excavation showing fine roots (painted white) within soil profile, which are critical for nutrient and water uptake

These observations would suggest that a fairly broad window of opportunity for nutrient uptake exists from before flowering to veraison in warm- to hot-climate vineyards. Post-harvest root flushes are also observed, although these are generally smaller in magnitude, and do not occur every year. In these vineyards, fine roots can survive into winter, and may even continue to absorb some nutrients after leaf-fall.

Impact of reserves on shoot growth and yield

High carbohydrate and nutrient reserves, and in particular stored N, will encourage strong spring shoot growth and promote higher bud fruitfulness. In research trials where carbohydrate reserves had been reduced by partial or complete defoliation, reductions in shoot growth rates and diameters were observed in the following spring (Bennett et al. 2005; Smith & Holzapfel 2009). Over successive seasons, reductions in shoot growth caused by low reserves can also be accompanied by reduced bud fertility and lower flower numbers on bunch inflorescences (Figure 6). The subsequent processes of flowering and fruit-set are also influenced by carbohydrates, but the supply from current photosynthesis is more important than that from stored reserves (Rogiers et al. 2011).



Figure 6: Numbers of flowers on bunch inflorescences can be negatively affected by low grapevine carbohydrate reserves

There is evidence that N reserves play a greater role than carbohydrates in regulating shoot growth after bud-break, but the effects of the two can be difficult to separate. However, grapevines will use stored N to support initial shoot growth irrespective of soil N availability, and then transition to new-season uptake in the weeks leading up to flowering. The N status of the vine at the end of the post-harvest period will therefore have an important impact on the development of the canopy in the following spring.

Post-harvest vine management: Carbohydrate storage

For carbohydrate storage to occur after harvest, continued photosynthesis is required. This means maintaining the leaves in reasonable condition for as long as possible after harvest with adequate irrigation and nutrition. Effective pest and disease control through the season is also important to ensure a healthy canopy. Apart from the loss of functional leaf area, infections with powdery or downy mildew can considerably disrupt and reduce carbohydrate export from the leaves. (See www.gwrdc.com.au/resource_categories/pest-and-disease for more information.) The carbohydrate status of vines at harvest is most influenced by seasonal weather conditions, yield and harvest date. In cooler climates, vine carbohydrate reserves are largely restored by harvest (Figure 7). Late-season defoliation may still have an impact on carbohydrate reserve accumulation, but this needs to occur across several consecutive seasons before effects on growth and yield are observed (Greven et al. 2012).



Figure 7: Grapes just before harvest. Vine carbohydrate reserves are largely restored by harvest in cool climates but in hot climates there is a greater reliance on the post-harvest period for replenishment of reserves

In hot irrigated regions, at the other end of the climate spectrum, yields are typically higher and temperatures during the ripening period are often in the optimal range for photosynthesis. If vines are water-stressed during these periods or suffer significant heat damage to the leaves, the canopy may not have the capacity to ripen fruit and store reserves at the same time (Figure 8). In these situations, the vine has a greater reliance on the post-harvest period for reserve replenishment. The loss of leaf area following machine harvesting can impact on reserve storage, but provided this doesn't exceed 40–50% and the remaining leaves remain healthy, the effects will be minimal.



Figure 8: Vine canopies in poor condition may not have enough capacity to ripen fruit and store reserves at the same time

A direct measurement of carbohydrate reserve status at harvest provides the most definitive method for assessing the importance of the post-harvest period. However, a general guide to the need for post-harvest replenishment can be obtained from the vine yield. Slow or uneven berry ripening and delayed or incomplete cane lignification can provide additional indicators that vines have experienced a shortage of carbohydrates during the season. With lower-yielding vines up to about 10 t/ha, sufficient carbohydrates will usually be stored in parallel with fruit ripening if growing conditions have been favourable. Post-harvest reserve storage becomes more important as yields increase from 10 to 20 t/ha, but other than maintaining some irrigation if rainfall is low through late summer and early autumn, little management intervention is required. However, for fruit yields from 20 to 30 t/ha and above, the post-harvest period becomes increasingly critical for sustaining long-term vine productivity and some 6–8 weeks may be required for full restoration of reserves. In these situations, it is important that irrigation is used to maintain leaf photosynthesis after harvest, and for early harvest dates in particular, that leaf and canopy function are retained through any remaining summer heat events.

Post-harvest vine management: Nutrition

For the overall management of grapevine nutrition, using combinations of annual petiole test results, knowledge of soil conditions, visual canopy assessments and juice N concentrations (if available) is currently the best way to assess vineyard nutrient status. Nutrient removal rates with fruit can also be considered (Nicholas 2004). Post-harvest fertiliser applications provide an opportunity to address any late-season nutrition issues, promote the retention of leaves for a longer period into autumn, and build

up nutrient reserves for the following season. However, nutrition strategies may vary between regions, and according to the time available for mobile nutrients such as N to move into the root-zone and be taken up by the vine before leaf-fall.

Hot-climate irrigated vineyards

The majority of growers in hot-climate irrigated regions apply fertiliser during the post-harvest period, with N, P and K the most commonly applied nutrients. Post-harvest N applications in particular can assist with maintaining functional leaf area for a longer period after harvest, and given the role of stored N in supporting spring shoot growth, it is also important that N reserves are replenished in the post-harvest period. Of the other main macronutrients, P and K may also be taken up in the post-harvest period, but as these have much lower mobility in the soil, timing of application is less critical than for N.



Figure 9: Early season application of nitrogen may be beneficial for vines with known deficiencies

The amount and type of fertiliser applied after harvest needs to take into account the overall nutritional status of the vines. For N, which is the most important nutrient to consider for the post-harvest period, about one quarter to a third of the total seasonal requirement might typically be applied in this period. If, at harvest, vines have a canopy in good condition and no major indications of N deficiency, fertiliser applications may be able to wait until early autumn.

Alternatively, earlier applications may be beneficial for vines with known marginal N concentrations (Figure 9). In both cases, irrigation should be managed to minimise water movement and loss of soluble N forms below the rootzone.

Warm-climate vineyards

Warm-climate viticultural regions in Australia represent a diverse array of growing conditions, from low-yielding vineyards with sometimes very limited water availability though to intermediate-yielding vineyards with reliable water supplies. Where canopies have suffered leaf damage or water stress during the ripening period, N applications with irrigation shortly after harvest can assist with maintaining leaf function into the post-harvest period.



Figure 10: Vineyard following harvest with obvious leaf senescence

Even for low-yielding vineyards, storage of N reserves will also occur in the post-harvest period. In situations where irrigation water is limited and chances of post-harvest rainfall low, there will be limited movement of nutrients into the rootzone. Any fertiliser applications should be delayed until the next season to avoid leaching losses over winter.

Cooler-climate management

As the duration of the post-harvest period decreases, the scope for varying management practices during this time also decreases. With a short post-harvest period, there may only be the opportunity (or need) for one or two irrigations timed with a fertiliser application before leaf-fall. For locations where leaf-fall normally occurs shortly after harvest, vine nutrition by default is managed with fertiliser applications earlier in the season. Soil or foliar N applications around veraison will primarily be directed to the fruit, but applications closer to harvest may be effective for increasing leaf and reserve N later in the season.

Post-harvest vine management: Irrigation

Where possible, some water should be saved for use during the post-harvest period. This allows for some irrigation to maintain leaf function, and in the absence of rainfall, to help move any applied fertilisers into the rootzone. In the event that no water is available for irrigation during the post-harvest period, research suggests that even high-yielding vines can tolerate this for one

or two seasons. Carbohydrate reserve accumulation in the roots may be reduced, but provided that vines have had reasonable irrigation or rainfall prior to harvest, the amount of reserves stored should still be adequate. However, if dry post-harvest conditions are anticipated, it is advisable to save some water for an irrigation at the end of the season to avoid entering vine dormancy with a dry soil profile. An irrigation to bring the main part of the rootzone back into the readily available water range in late winter, or several weeks before bud-break, may also suffice and will also assist in leaching applied salts from the rootzone. Vines that reach bud-break with a dry soil profile can have uneven and reduced shoot growth, possibly as a result of a decline in root function and delay in vine rehydration (Keller 2010). Trials have also shown delays in ripening due to increased crop load, as dry soils through bud-break appear to have a greater effect on canopy growth than yield (Holzapfel & Smith 2012).



Figure 11: In dry soils, irrigation prior to bud-break can avoid uneven and reduced early season shoot growth

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References and further reading

Bennett J, Jarvis P, Creasy GL & Trought MCT (2005) Influence of defoliation on overwintering carbohydrate reserves, return bloom, and yield of mature Chardonnay grapevines. American Journal of Enology and Viticulture 56(4): 386–393.

Comas LH, Bauerle TL & Eissenstat DM (2010) Biological and environmental factors controlling root dynamics and function: effects of root ageing and soil moisture. Australian Journal of Grape and Wine Research 16: 131–137 (http://dx.doi.org/doi:10.1111/j.1755-0238.2009.00078.x).

Greven MM, Neal SM, Tustin DS, Vasconcelos MC & Boldingh H (2012) The effect of postharvest defoliation on Marlborough Sauvignon Blanc productivity. NZ Winegrower Oct/Nov 74–77.

GWRDC (2009) Management of carbohydrate reserve accumulation as a tool for regulating vine productivity and fruit quality. Final Report for Project CSU 05/01. 83 pp. Available at www.gwrdc.com.au/wp-content/uploads/2012/09/CSU-05-01.pdf

Holzapfel BP & Smith JP (2012) Developmental stage and climatic factors impact more on carbohydrate reserve dynamics of Shiraz than cultural practice. American Journal of Enology and Viticulture 63(3): 333–342. (http://dx.doi.org/doi:10.5344/ajev.2012.11071)

Holzapfel BP, Smith JP, Field SK & Hardie WJ (2010) Dynamics of carbohydrate reserves in cultivated grapevines. In Janick J (ed.) Horticultural Reviews, vol. 37, John Wiley & Sons: Hoboken, NJ, pp. 143–201 (http://dx.doi.org/doi:10.1002/9780470543672.ch3).

Keller M (2010) The Science of Grapevines: Anatomy and Physiology, Academic Press: Burlington, MA, ISBN 9780123748812, 378 pp.

Nicholas P (2004) Soil, Irrigation and Nutrition, Grape Production Series, no. 2, Winetitles: Adelaide, ISBN 9781875130405, 201 pp.

Rogiers SY, Smith JP, Holzapfel BP & Hardie WJ (2011) Soil temperature moderates grapevine carbohydrate reserves after bud break and conditions fruit set responses to photoassimilatory stress. Functional Plant Biology. 38(11): 899–909 (http://dx.doi.org/10.1071/FP10240).

Smith JP & Holzapfel BP (2009) Cumulative responses of Semillon grapevines to late season perturbation of carbohydrate reserve status. American Journal of Enology and Viticulture 60(4): 461–470.

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