Water stress at flowering and effects on yield

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Introduction
A search of the grape literature reveals a considerable number of reports of the effect of water deficit on berry development and ripening, however, there are few reports on the effect of water deficit specifically during the flowering—setting period. Is this a result of the general acceptance that the avoidance of water deficit or stress during *Vitis vinifera* flowering is critical and not worthy of investigation? In contrast, the influence of rootzone available soil water at flowering on cereals is well documented (Figure 1). Water deficit at germination reduces the number of plants/m², while during the vegetative stage deficit will reduce the number of grain heads per plant and if it continues, the number of kernels per head. Water deficit around flowering will also reduce the number of kernels per head and also final kernel size in a similar manner to which water deficit after flowering in grape berries will reduce final berry size. A similar understanding exists for a range of other annual crops and for some, complex mathematical models have been developed to describe the relationship between evapotranspiration deficit and plant behaviour (see examples cited in Deficit Irrigation Practices, FAO Water Reports 22, 2002). Most annual crops exhibit a high sensitivity to water deficit at flowering with effects manifesting as reduced yield caused by, for example, smaller or fewer seeds, reduced boll or tuber size.

Water stress at flowering in *Vitis vinifera*
Hardie and Considine (1976) investigated the effects of severe water stress on fruiting, container grown Cabernet Franc vines, including water deficit during the flowering—setting period. Withholding water for a 22-day period commencing at flowering resulted in a significant reduction in berry volume and weight, the number of berries per cluster, cluster weight and clusters per vine (Figure 2). Yield per vine of deficit-irrigated vines was about 6% of well-irrigated vines, highlighting the critical importance of avoiding water stress during flowering if an economic yield is to be achieved. The loss in yield reported by Hardie and Considine (1976) was accentuated by the severe water deficits that could be imposed on container-grown vines in a free draining soil with a low water holding capacity and Myburg (2003) demonstrated that with vines in the field with a larger more exploratory root system, and greater soil water reserves, comparative yield losses could not be...
induced. Withholding micro-sprinkler irrigation on mature, field-grown Sultanina vines for a period of about three weeks prior to, and including flowering, did not result in any significant loss in yield or vegetative growth. There was a tendency for smaller berries and reduced bunch weight and a visual observation of increased berry loss on deficit vines after flowering that resulted in a 15% loss in yield compared to non-deficit vines.

Two factors may have contributed to minimising the effect of water deficit during flowering in the Myburg experiment:

i) The rootzone was near field capacity at the commencement of the deficit period and was only -0.070 Mpa at the end of the treatment period, only slightly drier than suggested critical values required for the control of vegetative growth and yield. ii) The steady decline in soil water availability during the deficit period may have provided sufficient ‘buffering’ through greater root exploration or adaptation.

Although less than the 94% loss in yield reported by Hardie & Considine (1976), such loss in yield would have an economic impact and indicates that the generally accepted practice of maintaining rootzone soil water close to field capacity during the flowering—setting period will ensure maximum berry set.

In the SA Riverland, field-grown Shiraz vines exhibited crop loss when the rootzone soil available water fell below the refill line at flowering and continued to decline during the flowering—setting period. At harvest, there were about nine fewer berries per bunch (Table 1) compared with well-irrigated vines. In this experiment, deficit-irrigated vines were not re-irrigated until veraison by which time berry size was also less than well irrigated vines; however, if berry weight had not been reduced there could have been a 2.4 T/ha loss in crop at harvest solely due to fewer berries per bunch. The actual loss in yield through the combination of fewer and smaller berries was about 20% compared to well irrigated vines. In previous seasons when soil water content did not fall below the refill line during the flowering and setting period there was no reduction in the number of berries per bunch. This highlights the need to accurately define the irrigation refill line for each soil type being irrigated.

Van Rooyen et al (1980), in a series of mathematically determined experimental treatments conducted in 16m³ drainage lysimeters each containing two Waltham Cross grapevines grafted onto Jaques rootstock, concluded that to ensure maximum yield, the soil matrix potential should not be more negative than about 5 kPa during Phase I of berry growth and no more than about 27 kPa during Phase II. These values are surprisingly low, as 5 kPa in some soils could indicate potential water logged conditions, however, these values were derived from surface contours of yield and not imposed soil water status. Although derived, these results support the recommendation that soil water status should be high during the flowering—setting period if maximum berry set is to be achieved and not less than the irrigation refill line.

### Berry developmental sensitivity to water deficit

Hardie and Considine (1976) reported that the flowering—setting period was the most sensitive period for yield loss and was about twice as sensitive to loss in berry weight per day of stress compared with the period before veraison (Figure 3) and about six times more sensitive than the period before harvest when berries were moderately resistant to stress.

McCarthy (2000) reported a similar sensitivity to water deficit during four periods of Shiraz berry development with the period after flowering being the most sensitive to soil water deficit (Figure 4).

Water deficit applied either before or after veraison resulted in a similar loss in berry weight per unit of water stress. Water deficit prior to harvest did not cause any apparent loss in berry weight, however, the intrinsic nature of ripening Shiraz berries to lose weight during the latter stages of ripening (McCarthy 1999) probably masked any treatment effect.

Although some of the periods of water deficit induced on Sultanina vines (Myburgh 2003) were too short to have significant effects, water deficit during the early stages of berry development tended to have more negative effects on yield than when water deficit was applied later in the season during berry ripening. Reduced cell division is generally attributed to be the cause of increased sensitivity of berries to water deficit post-flowering.

### Table 1. Effects of water deficit at flowering on yield components of Shiraz vines in the SA Riverland

<table>
<thead>
<tr>
<th></th>
<th>Irrigated</th>
<th>Deficit</th>
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</thead>
<tbody>
<tr>
<td>Berries per bunch</td>
<td>68</td>
<td>59</td>
</tr>
<tr>
<td>Bunches per vine</td>
<td>166</td>
<td>164</td>
</tr>
<tr>
<td>Berry wt (g) at harvest</td>
<td>1.2</td>
<td></td>
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<tr>
<td>Fruit wt/vine (kg)</td>
<td>13.5</td>
<td>11.6</td>
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<tr>
<td>Yield (T/ha)</td>
<td>16.9</td>
<td>14.5</td>
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</table>

### Figure 3. Yield loss [g/vine] per day of water stress for five deficit treatments imposed on potted Cabernet Franc vines. Number in brackets indicates the number of days of water deficit imposed either at flowering (F), pre veraison (Pre-V), veraison, post veraison (Post-V) or pre-harvest (Pre-H). Redrawn from Hardie & Considine (1976)

### Figure 4. Relationship between cumulative daily soil water deficit [mm] below refill line and berry weight at 22.5°Brix as percent of fully irrigated for post flowering, pre and post veraison and pre-harvest water deficit treatments. Data points for each treatment are the calculated soil water deficit and berry weight for three consecutive seasons. In the absence of any deficit, berry weight of all treatments was assumed to be equal to fully irrigated
Pre-flowering water deficit
In regions with inadequate spring rainfall, irrigation is recommended to maintain the soil profile in a well-watered state to encourage vegetative growth (e.g. Hardie and Martin 1989) and this is generally the case in Australia. Few studies have however been conducted to examine the effects of soil water deficit during the budburst to flowering period on yield although the applicability of RDI during this growth stage is of increasing interest. In many regions, spring rainfall will minimise the effects of RDI between budburst and flowering, however, in districts where irrigation is normally applied after budburst the use of RDI to control excessive early season vegetative growth and interactions with bunch development should be investigated. McCarthy (unpubl.) demonstrated a non-significant response to irrigation between budburst and flowering in the Barossa Valley, except under the extreme conditions of the 1982-83 drought when autumn–winter rainfall was much below long term average. The yield of unirrigated vines at harvest in March 1983 was less than half that of previous seasons (Figure 5) resulting from fewer bunches per vine due to poorer budburst and smaller berries. Surprisingly there were significantly more berries per bunch at harvest suggesting a compensatory response to the reduced bunch number per vine.

Conclusions
The industry-wide practice of minimising soil water deficit during the flowering–setting period is supported by research outcomes both nationally and internationally over many years and the effects of water deficit in the early stages of berry expansion are the basis of Regulated Deficit Irrigation practices. While maintaining high levels of soil-available water during the flowering–setting period will contribute to ensuring a high percentage of flowers developing into berries, other factors such as temperature extremes are also critical. In high summer rainfall regions where bunch rots can often be problematical, vineyard operators perhaps need to consider whether berry set could be reduced in a controlled manner using water deficit to produce a more open structured bunch which is less susceptible to disease.

References