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Fruitfulness in grape-vines: Effects of water stress

by

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Die Fruchtbarkeit der Rebe: Auswirkungen von Wassermangel

Zusammenfassung. — Reben der Sorte Cabernet Sauvignon (*Vitis vinifera* L.) wurden in nicht dränierten Gefäßen im Gewächshaus herangezogen; die Wasserversorgung wurde durch Wägen kontrolliert. Bei den drei Varianten wurde die Pflanzerde bei Erreichen eines Wassergehaltes von 60% (A), 40% (B), oder 20% (C) der Feldkapazität wieder gegossen. Mit zunehmendem Wassermangel nahm die Menge des benötigten Wassers ab, entsprechend der wachstumsbedingten Ausdehnung der Triebe. Bei der Ernte 13 Wochen nach dem Austrieb betrug das Gewicht der C-Pflanzen weniger als zwei Drittel der A-Pflanzen. Die Fruchtbarkeit (Anzahl und Gewicht der Infloreszenzprimordien) war mit zunehmendem Wassermangel progressiv vermindert. Anzahl und Gewicht der Blattprimordien blieben unverändert.

Introduction

The fruitfulness of grapevine buds is affected by both light intensity and temperature (Buttrose 1969). In the field relative humidity of the air and availability of water could be related to temperature and light conditions in a particular season, and might also influence fruitfulness. No attempt appears to have been made to measure what effect water stress has on fruitfulness of grapevines, and this paper reports such an attempt.

Materials and Methods

Cuttings of dormant one-year-old canes of *Vitis vinifera* L. (cv. Cabernet Sauvignon) were collected in the field in July, 1972, and stored at 4 °C. Roots were established on cuttings as previously described (Buttrose 1968). Sixty rooted cuttings were weighed on September 9 and planted into 2.5 l undrained plastic containers containing 2.0 kg (dry weight) of potting compost (U.C. Mix). A gravel mulch was layered on the surface of the compost to reduce evaporation. Sufficient distilled water was added to each container to bring the mix to 75% of field capacity (825 g H_2O/2 kg dry weight). Pots were positioned in a glasshouse with a mean temperature of 24 °C (mean maximum 30 °C, mean minimum 18 °C) and natural sunlight reduced by approximately 66% with roof shading.

Buds burst during the second week after planting, and one month after planting, on October 5, the most vigorous shoot on each plant was chosen and the remainder removed. Shoot length averaged 14.0 cm and the number of nodes visible below the apex averaged 7.3. During the first month all pots were brought to 75% of field capacity with distilled water, by watering to weight, at 3 or 4-day intervals. On October 5 treatments were begun. These involved allowing water contents to fall to certain levels before re-watering to 75% of field capacity, and were as follows:

A — fall to 60% of field capacity,
B — fall to 40% of field capacity,
C — fall to 20% of field capacity.

Treatments will be referred to subsequently as A, B or C. Each plant was checked daily, water usage recorded, and water added when required. Preliminary tests had shown that wilting point of similar plants in this mix was at 6.3% of field capacity, but growth ceased well before water was depleted to this level. Evaporation of water from containers lacking plants was also measured.

Shoot length was measured on October 5, 12, 13 and 16, and thereafter each day until November 9, and then at less frequent intervals until harvest on December 20, 13 weeks after bud burst. The number of nodes on the main shoot was also recorded at intervals. At harvest leaves were stripped from plants and their weight measured after oven-drying. Compost was washed from roots which were then kept moist by enclosing in a polythene bag, and the defoliated plants were stored at 4 °C. Plants could be taken from storage at convenience for bud examination. All plants were examined within 25 days of entering storage.

The most-basal 13 buds on the main shoot were dissected under a low-power microscope and observations made according to earlier methods (Buttrose 1969) of the number of bunch primordia and the number of leaf primordia in each bud. In addition, the total weight of bunch primordia on the one hand, and of leaf primordia on the other, found in each bud, was measured by weighing on a Cahn electromicrobalance accurate to $\pm 5 \mu g$. When buds had been examined, all shoot material and in addition the root system from each plant was dried and weighed.

Results

a) Water usage

Evaporation from containers lacking plants varied little from day to day, and averaged 25.1 ± 0.9 ml/day for A, 22.3 ± 1.2 ml/day for B and 20.2 ± 1.1 ml/day for C. Water loss (evapo-transpiration) from containers with plants varied widely from day to day, and this variation was obviously associated with variations in ambient tem-

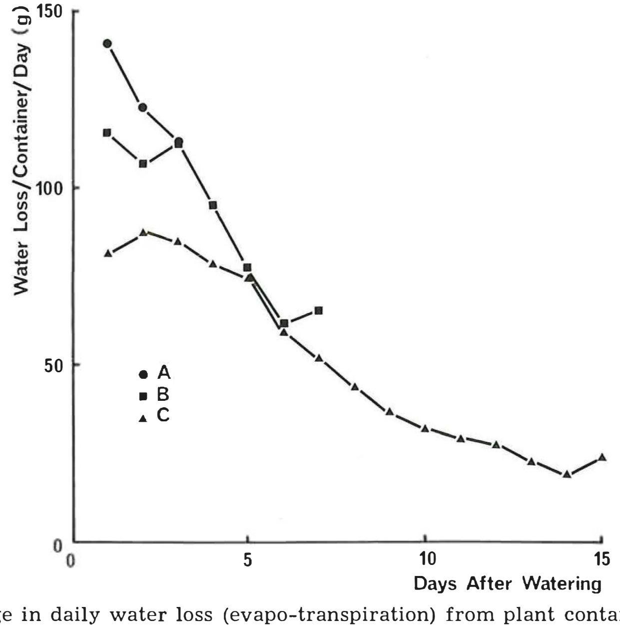


Fig. 1: Change in daily water loss (evapo-transpiration) from plant containers with lapse in time after watering.
Die Veränderung der täglichen Wasserabgabe (Verdunstung, Transpiration) der Pflanzengefäße mit zunehmendem Wassermangel.

Table 1

Amount of water lost (g/day evapo-transpiration) from pots containing plants of different shoot length categories (means of 20 values[1]))

Menge der Wasserabgabe (Verdunstung, Transpiration in g/Tag) der Gefäße mit Pflanzen verschiedener Trieblänge (Durchschnitt von 20 Werten)

	Length of shoots (cm)											
	37—39			40—42			43—45			46—48		
Treatment	A	B	C	A	B	C	A	B	C	A	B	C
Water lost	111	100	80	118	102	82	123	102	87	131	106	96
L.S.D. (5%)		13.5			14.8			20.2			16.4	

[1]) Water usage at any time during the period of daily measurements (October 17 to November 9) was related to shoot length, except that water usage data for B was restricted to the first 3 days after rewatering, and for C to the first 5 days after rewatering. More than one value may have been obtained from a given plant, but a minimum of 8 plants per treatment was available to provide data for a length category.

perature and humidity. Rewatering of plants of a given treatment was however staggered in time, so that much of this variation was cancelled in summarizing results. It was found that with lapse of time after watering the amount of water lost per day began to decrease immediately for A, by the 4th day for B and by the 6th day for C (Fig. 1). During the period October 17 to November 16 most plants from A required watering every 3 days, from B every 6 days and from C every 13 days.

Fig. 1 indicates that immediately after watering, evapo-transpiration for treatment A was greater than for treatment C, but plants differed in size due to treatment, and evaporation from frequently-watered containers was greater. When plants of similar shoot length were compared, it was established (Table 1) that A plants did indeed use more water per day than C plants because the difference was greater than could be due to differences in evaporation. Because of both this and their smaller size (see below), C plants required much less total water than A plants, with B plants intermediate. Data to illustrate this were assembled for the 8-week period October 14 — December 8 (Table 2), and they show that A plants required about twice as much water as C plants.

b) Shoot growth

The increase with time in shoot length of one typical plant from each treatment during the period October 5 to October 30 is shown in Fig. 2. The A shoot grew

Table 2

Total water lost over the period October 14 to December 8, and portion calculated as due to transpiration[1]) (l/plant)

Gesamte Wasserabgabe in der Zeit vom 14. Oktober bis 8. Dezember und errechneter Anteil der Transpiration (l/Pflanze)

Treatment	Water lost	Transpiration
A	8.26 ± 0.34	6.88
B	7.10 ± 0.24	5.89
C	4.30 ± 0.24	3.20

[1]) Evaporation taken as 25 g/day for A, 22 g/day for B, 20 g/day for C.

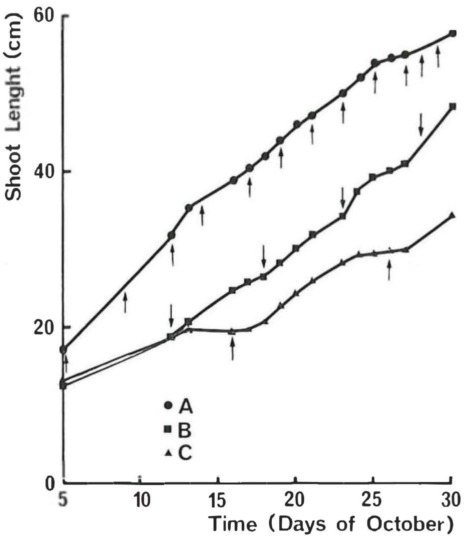


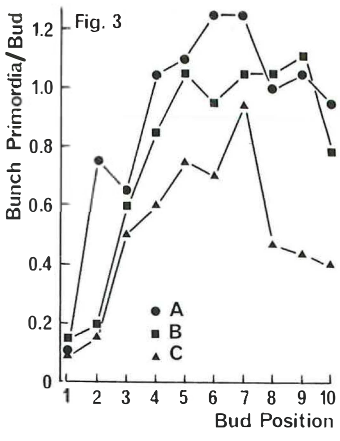
Fig. 2: Changes in shoot length of one representative plant from each treatment during the period October 5—30. Plants selected had a shoot length on October 30 closest to the mean shoot length for their treatments. Arrows indicate watering times.
Veränderung des Längenwachstums je einer repräsentativen Pflanze aus jeder Versuchsvariante in der Zeit vom 5.—30. Oktober. Die Sproßlänge der ausgewählten Pflanzen lag am 30. Oktober dem Durchschnittswert Ihrer Variante am nächsten. Die Pfeile geben die Bewässerungszeitpunkte an.

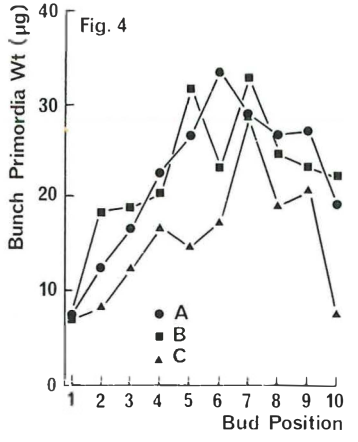
overall faster than the B which grew faster than the C. The slackening in growth rate of A on October 25 was subsequently corrected by nutrient application. Growth of A was unrelated to time of watering, growth of B slackened one or two days before re-watering, and growth of C slackened several days before. The C shoot did not regain rapid growth rate until more than 24 hours after re-watering, but then growth rate did not appear to differ from that of A for one or two days. Woody internodes (brown, not green) were first observed on C shoots. Thus on December 1 an average of 2.8 internodes at the base on C shoots were woody, compared with 0.2 internodes for A and 0.1 for B. By December 15 A had an average of 8.5, B 7.8 and C 6.3 woody internodes.

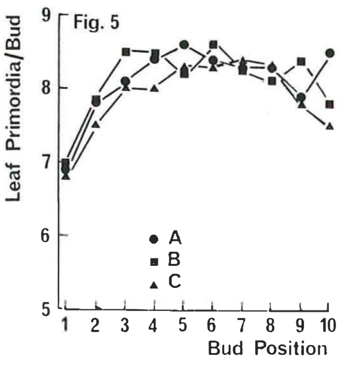
Table 3

Effect of treatment on shoot length, node number and plant dry weights at harvest
Auswirkung der Wasserversorgung auf Trieblänge, Anzahl der Nodi und Trockengewicht der Pflanze bei der Lese

	Treatment			
	A	B	C	L.S.D. (5%)
Shoot length (cm)	107.9	97.3	74.3	10.9
Node number	26.1	25.7	21.6	1.6
Leaf dry weight (g)	10.2	9.5	6.0	0.6
Cane dry weight (g)	8.5	7.2	3.7	0.9
Root dry weight (g)	9.9	9.8	6.6	1.2







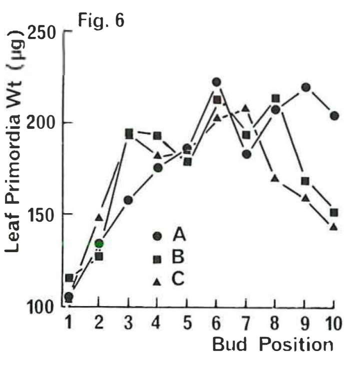


Fig. 3: Mean number of bunch primordia per bud for buds along the shoot after harvest. Results of statistical analysis: effects of bud position significant ($p = 0.001$); effects of treatment significant ($p = 0.001$); from overall trends A > B > C.
Durchschnittliche Anzahl der Infloreszenzprimordien je Knospe nach der Ernte in Beziehung zur Insertionshöhe. Ergebnisse der statistischen Analyse: Einfluß der Insertionshöhe signifikant bei $p = 0{,}001$; Einfluß der Behandlung signifikant bei $p = 0{,}001$; allgemeine Tendenz: A > B > C.

Fig. 4: Mean fresh weight of bunch primordia tissue per bud. Results of statistical analysis: effects of bud position significant ($p = 0.001$); effects of treatment significant ($p = 0.001$); from overall trends A = B > C.
Durchschnittliches Frischgewicht der Infloreszenzprimordien je Knospe. Ergebnisse der statistischen Analyse: Einfluß der Insertionshöhe signifikant bei $p = 0{,}001$; Einfluß der Behandlung signifikant bei $p = 0{,}001$; allgemeine Tendenz: A = B > C.

Fig. 5: Mean number of leaf primordia per bud. There was no significant effect of treatment.
Durchschnittliche Anzahl der Blattprimordien je Knospe. Kein signifikanter Einfluß der Behandlung.

Fig. 6: Mean fresh weight of leaf primordia tissue per bud. There was no significant effect of treatment on overall trends.
Durchschnittliches Frischgewicht der Blattprimordien je Knospe. Kein signifikanter Einfluß der Behandlung auf die allgemeine Tendenz.

Results of measurements made at the time of harvest are shown in Table 3. Length of shoots, number of nodes and dry weight of plant parts were all reduced by water stress; cane dry weight was most affected.

c) Fruitfulness

The number of bunch primordia per bud was low at basal nodes, reached a maximum at about node 7, and then declined (Fig. 3). Analysis of variance for the overall data showed that the number of primordia per bud was significantly ($p = 0.001$) affected by bud position, and also ($p = 0.001$) by treatment. There was no interaction of bud position and treatment. The number of primordia per bud decreased with increase in water stress. Data on weight of bunch primordia tissue per bud (Fig. 4) was analysed after transformation to logarithms. Again, effects of both bud position and treatment (severe water stress, treatment C) were highly significant ($p = 0.001$) and there was no interaction. There was a decrease in primordia weight with a high level of stress. Treatment had no effect on either number (Fig. 5) or weight (Fig. 6) of leaf primordia per bud up to node 8. From visual examination it was noted that all buds at nodes up to node 8 were mature, but this did not necessarily apply at more distal positions. The lack of maturity distal to node 8 is evidenced by the reduction in number and weight of primordia.

Discussion

Buds at the base of grapevine canes are less fruitful than those at more distal positions (May and Cellier 1973), and in the field Cabernet Sauvignon normally has a fruitfulness of at least 2 bunch primordia per bud on established plants. Fruitfulness of buds along the shoot also changed in the present experiment, but it was only approximately 1 bunch primordium per bud. This fruitfulness is close to that found for buds on comparable plants of Muscat Gordo Blanco and Shiraz when grown at 25 °C in growth cabinets (Buttrose 1970), and on similar potted plants of Muscat Gordo Blanco when grown outside in full sunlight in summer (unpublished data).

The data on water usage and shoot growth establish that treatment C was under water stress relative to treatment A. Some measurements from treatment B did not differ from those of treatment A, although they were higher. This suggests firstly that stress on B plants was little greater than that on A plants, and secondly that A plants were unstressed and may be regarded as a control treatment.

The results indicate that fruitfulness of grapevine buds can be depressed by water stress. In the field, stress is most likely to occur at times of high temperature/light, and it would therefore act against the influence of these factors in promoting fruitfulness. Irrigation during the period of bud formation could be important in influencing potential crop in areas with a dry sunny climate.

Fruitfulness of C buds was only about two-thirds of A buds, and a similar relationship held between the treatments in respect of shoot length and dry weights. It is possible that the effect on fruitfulness was part of a general effect on plant growth. Loveys and Kriedemann (1973) have demonstrated for the grapevine that water stress results in a reduction in photosynthesis, so that stressed plants may have a shortage of available carbohydrates. There is a certain amount of evidence that the induction of bunch primordia in grapevine buds is related to supply of available carbohydrates (Buttrose 1969). It was interesting to note that the one to two day delay in re-commencing active shoot growth of C shoots corresponded with a similar delay in leaves re-establishing normal photosynthesis following water stress (LOVEYS and KRIEDEMANN 1973).

MAY (1964) working with field plants of Sultana (Thompson Seedless) found that the number and size of leaf primordia was greater in fruitful than in unfruitful buds, and that within fruitful buds weight of leaf primordia was related to weight of bunch primordia. Differences he recorded were small but significant. In the present work the leaf primordia in buds which had matured (nodes 1—8) were unaffected by water stress despite effects on fruitfulness.

Summary

Plants of *Vitis vinifera* L. cv. Cabernet Sauvignon were grown in undrained containers in a glasshouse and watering was controlled by weighing. There were three treatments with water contents of the growing medium falling either to 60% (A), 40% (B) or 20% (C) of field capacity before re-watering. As water stress increased the amount of water used decreased as did extension growth of shoots. At harvest 13 weeks after bud burst the weight of C plants was less than two thirds that of A plants. Fruitfulness (number and weight of bunch primordia per bud) was progressively depressed with increase in water stress. Number and weight of leaf primordia in buds were unaffected.

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