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Analysis of water consumption of various grapevine cultivars[1]

by

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Introduction

The problem of efficiency in water use has attracted the interest of many scientists during the last century. As early as 1883, Hellriegel (11) calculated the ratio between water consumption and dry matter production and termed it "transpiration coefficient". Since then many studies have been carried out on this subject using such terms as "transpiration ratio", "water requirement", etc. (2, 18). Some workers preferred the ratio photosythesis/transpiration as a measure and used the term "productivity of transpiration" (13).

Studies on this subject were carried out in lysimeters (2, 18) as well as in the field (2, 14, 16, 18). Field methods included gravimetric and gasometric methods. In the first case plants were harvested and analyzed in terms of yield and evapotranspiration, while in the second case fluxes and gradients of CO_2 and H_2O vapor above the canopies were analyzed. Gasometric methods also served to study individual plants (8). In some studies, CO_2 consumed was calculated as glucose and the amount of transpiration per unit glucose formed served as a measure of transpiration ratio (16, 19).

Information was accumulated on many species grown under different climatic conditions. However, there are some differences in the results obtained from different sources. Shantz and Piemeisel (18) reported transpiration coefficient values for 150 species, ranging from 216 to 1131, while Dillman (5) found, in the course of 9 years of investigation that the value for alfalfa varied from 602 to 1036, while sorghum under the same conditions ranged between 210 and only 284. Grading of the species according to their water use efficiency by different scientists did not coincide (15, 18).

Woody plants were investigated less. However, the data of Hilgard (12) and Gardner *et al.* (9) indicate values similar to those of herbaceous plants. In grapevines under field conditions, the transpiration ratio was found to vary between 580 and 730 (3). The cultivar Semillon was found to use water somewhat more efficiently than Malbeck: 359 and 405 respectively (4).

The effect of climate was investigated by de Wit (22) and Arkley (1). Information concerning plant factors involved in efficiency of water use is inadequate, some data pointing towards the effect of growth, soil fertility, etc (20). Since water use efficiency is a product of two processes, photosynthesis and transpiration, and at least part of the diffusion pathways of CO_2 and H_2O vapor in the plant and its immediate environment is the same, it would seem logical that the ratio between these related processes should be investigated in relation to both internal plant factors, as well as environmental factors.

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Recent work on grasses (6, 7) reports differences in water use efficiency among clones due to plant factors like the number of vascular bundles in the leaves and amino acid content, but not due to stomatal density.

This paper reports results obtained for several cultivars within one species *(Vitis vinifera)* grown under identical climatic conditions. Analysis of the data was aimed at investigating differences both between and within the cultivars.

Materials and Methods

Rooted cuttings of grapevines *(V. vinifera)* of several cultivars were grown in lysimeters. The lysimeter consisted of a 10 liter plastic container filled with rinsed sand and connected to a second plastic container positioned beneath it by a plastic tube. The plants were irrigated with a measured amount of nutrient solution. The excess water or nutrient solution was drained through the connecting tube, accumulated in the lower container and was measured periodically. Each plastic pot contained one plant which trained two shoots without laterals. The shoots were tied vertically and their length was measured periodically. At the end of the season all plants were harvested and the dry weight of their roots, shoots and leaves was determined separately by drying them at 80° C for 24 hours. Leaf area was measured by punching disks, weighing them and multiplying the area with a weight of 1 gr, by the total leaf weight (21). The plants were arranged in a random block design. During the first season we examined eight cultivars replicated in six blocks. In the second season we tested three cultivars out of the former eight, replicated in 19 blocks.

Transpiration and photosynthesis of single leaves were measured by an open circuit system consisting of an infra red gas analyzer for CO_2 determination (URAS 2, Hartmann & Braun, West Germany) and LiCl electrical sensors for humidity measurements (Hygrodynamics U.S.A.). Single leaves were enclosd in a measuring chamber consisting of an exchangeable 0.01 mm thick polythene bag over a wooden base easy to attach to the petiol by means of soft rubber and wing nuts. Temperatures inside the chamber were kept similar to those outside within 1° C, by blowing air onto the outer walls of the polythene bag with a large fan. Circulation inside the chamber was achieved by a small fan mounted on the base of the chamber, and by blowing air at the rate of 9 l/min through the one litre chamber. Three such chambers were operated simultaneously under the natural conditions prevailing in a screen house. A gas selector switch (Gasumschalter, Hartmann & Braun, West Germany) enabled sampling, at two minute intervals, of the air passing through each chamber. Net photosynthesis and transpiration were calculated from the difference in the concentrations of CO_2 and H_2O vapor at the inlet and outlet of the chamber, and the rate of air flow.

Results

Eight cultivars commonly grown in Israel were tested for their water consumption. Six plants of each cultivar were tested individually. There were considerable differences among cultivars in respect to all parameters examined as shown in Table 1. The general tendency was towards increased efficiency of water use, (expressed as seasonal water consumption per unit of dry weight produced) with the increase in vigor. The more vigorous cultivars such as Sultanina (Syn. Thompson Seedless) and Perlette used water more efficiently than less vigorous

Table 1

Seasonal growth and water consumption of various grapevine cultivars

Cultivar	Perlet	Sultanina	Alphonse	Muscat Hamburg	Queen of the Vineyards	Chasselas	Dabuki	Pearl of Csaba	S.E.
Plant dry weight	c[1])	bc	abc	ab	ab	a	a	a	
(g)	338.6	301.6	241.0	205.0	197.5	139.0	133.6	132.1	35.5
Top dry weight	b	abc	abc	abc	abc	ac	c	abc	
(g)	128.2	125.6	112.1	85.0	96.0	66.5	63.7	68.7	13.9
Root dry weight	a	ab	abcd	abcd	abcd	abcd	ab	a	
(g)	210.6	173.5	128.9	120.5	101.5	72.5	69.9	63.3	26.1
Top/root ratio[2])	0.70	0.89	0.91	0.87	1.00	0.92	0.91	1.08	0.11
Water consumption litre	b	b	ab	ab	ab	ab	a	ab	
	100.4	93.3	89.7	80.8	80.5	64.1	53.2	62.3	10.5
Water consumption per unit	a	ab	abc	abc	abc	bc	abc	c	
dry weight (ml/g)	329	359	420	448	400	471	412	493	31.4

[1]) Values accompanied by different letters differ significantly at 5% level.

[2]) Differences in top/root ratio were insiginficant.

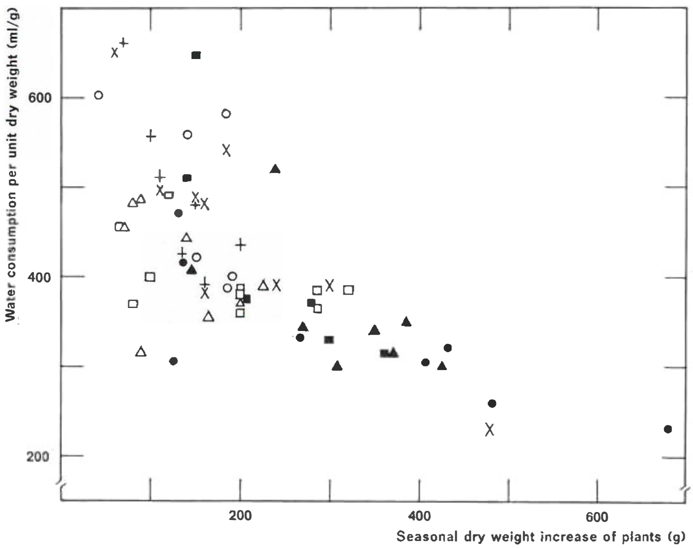

Fig. 1: The relation between water consumption per unit of dry weight and final dry weight of individual plants at the end of the growing season.

■ Alphonse ● Perlet + Pearl of Csaba
× Muscat Hamburg Δ Dabuki o Chasselas
▲ Sultanina □ Queen of the Vineyards

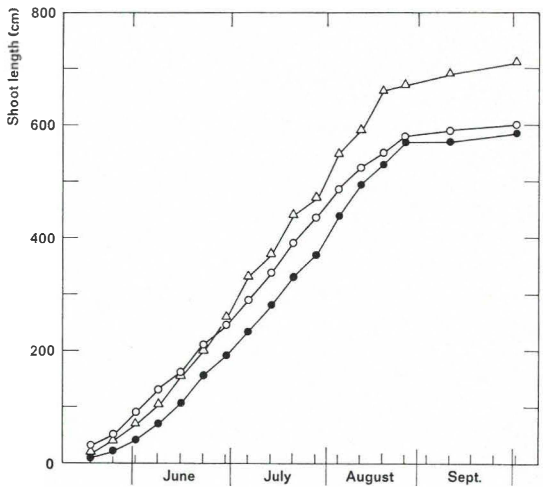

Fig. 2: Cumulative rate of shoot growth of three grape vine cultivars.
● Queen of the Vineyards Δ Sultanina o Muscat Hamburg

cultivars such as Pearl of Csaba. The correlation coefficient between the averages of final dry weight of seven cultivars (excluding Pearl of Csaba) and their water consumption per unit dry matter was $r = -0.845$ (significant at 1% level). Rank correlation for all eight varieties was $r = -0.744$ (significant at 5% level). Plotting the water use efficiency against vigor (expressed as weight of dry matter accumulated) of individual plants of all cultivars showed that this relationship also holds true within varieties (Fig. 1). However, the specific differences between cultivars cause bending of the curve at both ends, thus creating a hyperbolic shape. The central part of this hyperbola is very close to linear. This indicates that an inverse relationship betweeen vigor and water consumption per unit dry weight exists between, as well as within, the cultivars. However, six replicates are not sufficient to permit analysis of specific differences between cultivars, which should be reflected by differences in the angles of the regression lines.

In order to determine whether there are specific differences between varieties due to vigor or in addition to it, we selected for the following season only three cultivars with similar vigor under our conditions: Muscat Hamburg, Queen of the Vineyards and Sultanina. Each cultivar was replicated 19 times. Average rate of shoot growth was higher in Sultanina, while Muscat Hamburg grew slightly better than Queen of the Vineyards (Fig. 2). Although in this experiment cultivars with similar and rather uniform vigor were chosen, significant differences between the cultivars were found in most of the measurements (Table 2). Sultanina was the most vigorous variety in terms of rate of growth, (Fig. 2) length of shoots and internodes, total dry weight and the average area of a single leaf, although the leaves were relatively thin, 0.64 g/100 cm^2 (assuming equal density for the leaves of all cultivars). Muscat Hamburg was medium in its vigor according to most of the

Table 2

Plant growth criteria and water consumption of three grape cultivars (average per plant)

	Queen of the Vineyards	Sultanina	Muskat Hamburg	P	L.S.D.[1])	Q[2])
Plant dry weight (g)	405.8	577.6	554.08	<0.01	96.5	115.6
Average fresh weight of one leaf (g)	2.14	2.37	2.37		—	—
Total leaf dry weight (g)	47.2	58.35	63.88	<0.05	11.17	13.37
Total leaf area (cm^2)	6691	9056	8188	<0.01	1515	1815
Average area of one leaf (cm^2)	94.3	120.6	108.3	<0.05	11.0	13.1
Shoot length (cm)	586.9	703.6	594.2	<0.01	62.99	75.4
Average length of one internode (cm)	5.0	5.8	4.6	<0.01	0.4	0.5
Top fresh weight (g)	462.8	650.7	491.3	<0.01	76.6	91.8
Top dry weight (g)	168.4	243.4	186.7	<0.01	33.1	39.7
Root dry weight (g)	201.6	232.9	331.7	<0.01	79.2	94.8
Top/root ratio	1.05	1.22	0.64	<0.01	0.37	0.44
Water consumption per plant (liter)	83.0	99.5	94.0	<0.01	71.2	85.2
Water consumption per unit dry weight (ml/g)	215.9	203.0	178.0		—	—
Water consumption per unit top dry weight (ml/g)	501.0	425.0	517.3	<0.01	52.8	63.2
Water consumption per unit leaves dry weight (ml/g)	1860	1800	1900		—	—
Water per unit leaf area ml/cm^2	12.99	11.62	13.99		—	—

[1]) For neighboring columns.

[2]) For alternate columns.

measurements mentioned above. However, this cultivar was outstanding in its low top/root ratio, mainly due to the considerable weight of its roots, and in spite of the high dry weight of leaves and the rather thick leaves (0.78 g/100 cm^2).

Queen of the Vineyards was the least vigorous in all respects except top/root ratio which was intermediate. The leaves were slightly thicker than those of Sultanina (0.71 g/100 cm^2).

The three cultivars did not differ significantly in their water use efficiency calculated for the whole plant dry weight, while calculations based on the top weight only, differed significantly, pointing to Sultanina as the most efficient cultivar. Since we learned that vigor affects the water use efficiency and found that the varieties differed in their vigor, further analysis of the data was carried out in order to determine specific differences between and within cultivars due to vigor or other factors.

When data of individual plants regardless of cultivars were employed, we found again a highly negative correlation between vigor expressed as dry weight accumulation of whole plants and water use for the entire experiment, $r = -0.682$. High correlations were also found within each variety, $r = -0.926$; -0.866; -0.831, for Muscat Hamburg, Sultanina and Queen of the Vineyards respctively. Further analyses regarding the slopes of the regression lines show significant differences between the slope of Muscat Hamburg and that of the other two cultivars (Fig. 3). This means that the quantitative effect of increasing vigor on the water use efficiency is smaller in Muscat Hamburg than in the other two cultivars, which did not differ in this respect. Since the range of whole plant dry weight differed among the three cultivars, this conclusion is valid only for the ranges tested; its validity for other ranges depends on whether and to what extent it is permissible to ex-

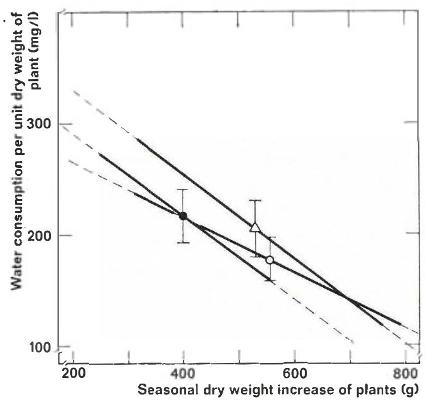

Fig. 3

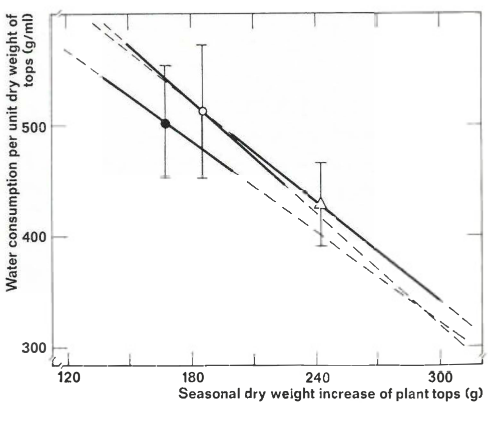

Fig. 4

Fig. 3: The relation between water consumption per unit of dry weight and total dry weight of individual plants.

- ● Queen of the Vineyards $y = -0.365\,x + 364$
- Δ Sultanina $y = -0.384\,x + 406$
- o Muscat Hamburg $y = -0.247\,x + 315$

Fig. 4: The relation between water consumption per unit dry weight of the plant top part and dry weight of tops.

- ● Queen of the Vineyards $y = -1.37\,x + 733$
- Δ Sultanina $y = -1.48\,x + 785$
- o Muscat Hamburg $y = -1.68\,x + 823$

trapolate the regression lines in each cultivar. Since the slopes of the regression lines of Sultanina and Queen of the Vineyards did not differ, we used analysis of covariance in order to eliminate the effect of vigor. Analysis of their common variance showed that the water consumption per unit dry weight was significantly higher in Sultanina than in Queen of the Vineyards. The adjusted means of water consumption per unit dry weight of plants were 226.6 for Sultanina and 193.9 for Queen of the Vineyards ($P < 0.01$, L.S.D. = 1.5). Queen of the Vineyards thus proved to be more efficient when the effect of vigor was eliminated.

In order to understand better the effects of the various plant components on the differences between the cultivars, we examined the relationship between the water consumed per unit of dry weight of the top (above ground parts), leaf area and leaf dry weight. Fig. 4 shows the data related to top part dry weight. The correlation between water consumption and top dry weight for all plants included in the experiment was high, r = —0.829. High correlations were also calculated within each cultivar. However, no differences were noted between the slopes of the regression lines. This means that as far as all above ground parts of the plants are concerned there were no specific differences in vigor among the cultivars. Similarly, no significant differences were observed in covariance analysis. The differences in water use efficiency per unit of plant top (Table 2) should presumably be attributed to the differences in vigor between cultivars, i. e. if we could select plants with the same top part dry weight, no difference in efficiency of water use should be found.

The correlation between the water consumed per unit leaf area and the final leaf area is shown in Fig. 5. A highly significant correlation for the entire experiment was found to be: r = —0.843. High correlations were also calculated within each cultivar, r = —0.928; —0.840 and —0.680 for Sultanina, Muscat Hamburg and Queen of the Vineyards, respectively. No significant differences were found between the slopes of the three regression lines. It may, therefore, be concluded that the increase in leaf area due to vigor was followed by a parallel increase in water use efficiency per unit leaf area among and within cultivars. However, the quantitative effect of vigor was similar in all three cultivars.

Analysis of covariance did show significant differences among the cultivars. The adjusted means of water consumption per unit leaf area were 11.62 ml/cm^2 for Sultanina, 12.99 ml/cm^2 for Queen of the Vineyards and 13.99 ml/cm^2 for Muscat Hamburg, ($P < 0.05$, L.S.D. = 1.85, Q = 1.54). Thus, we see that although the averages in Table 2 did not vary significantly, the adjusted means did differ due to elimination of the effect of vigor. Sultanina, which had the largest leaf area, was also the most efficient, while Muscat Hamburg was less efficient than Queen of the Vineyards in spite of its larger leaf area.

The relationship between water consumption per unit leaf dry weight and final dry weight of the leaves of individual plants is shown in Fig. 6. A high and significant correlation within and between cultivars was found. The correlation for the entire experiment was r = —0.850, while within the cultivars r = —0.920; —0.879; and —0.857 were found for Sultanina, Muscat Hamburg and Queen of the Vineyards respectively. This indicates that the water use efficiency increases with increasing vigor also when expressed as foliage dry weight. The slope of the regression line related to Muscat Hamburg differed significantly from the slope of the other two cultivars, i. e. the effect of increasing final leaf weight on water use efficiency is smaller compared with Sultanina and Queen of the Vineyards. Covariance analysis revealed a significant difference between Queen of the Vineyards and Sultanina, the former being more efficient. The adjusted means of water consumption per unit

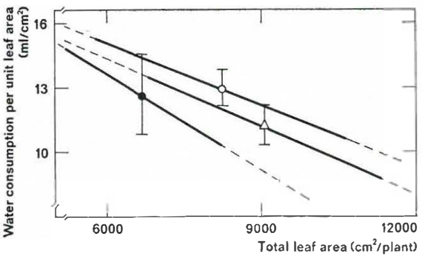

Fig. 5

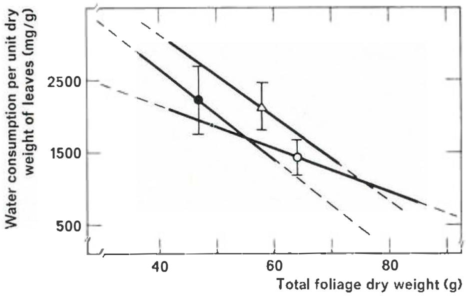

Fig. 6

Fig. 5: The relation between water consumption per unit leaf area and total plant leaf area.

●	Queen of the Vineyards	$y = -0.17 \cdot 10^{-2}x + 24.4$
Δ	Sultanina	$y = -0.11 \cdot 10^{-2}x + 22.0$
o	Muscat Hamburg	$y = -0.11 \cdot 10^{-2}x + 22.0$

Fig. 6: The relation between water consumption per unit dry weight of leaves and dry weight of leaves.

●	Queen of the Vineyards	$y = -31.8\ x + 3370$
Δ	Sultanina	$y = -29.0\ x + 3490$
o	Muscat Hamburg	$y = -14.8\ x + 2430$

leaf weight for final leaf dry weight were 17.0 for Queen of the Vineyards and 19.6 for Sultanina ($P < 0.05$, L.S.D. = 2.24).

Thus Queen of the Vineyards is more efficient than Sultanina when leaves of the same weight are compared. The values of water consumption per unit leaf dry weight shown in Table 2 did not differ significantly, probably because of the considerable weight of Sultanina leaves due to its vigor.

Significant correlations were calculated between leaf dry weight and the dry weight of the tops and whole plants within and between cultivars, $r = 0.767$ for tops and $r = 0.667$ for whole plants. Since no difference was found between the slopes of the regression lines, we used analysis of covariance. The adjusted means for dry weight of leaves on the top parts and whole plant dry weight are presented in Table 3. Muscat Hamburg was outstanding in its comparatively large leaf weight per unit of top part and whole plant dry weight, while Sultanina and Queen of the

Table 3

The adjusted means for dry weight of leaves on dry weight of the top part and whole plant of three grape cultivars

Cultivar	Whole plant (dry weight) g	Top of plant (dry weight) g
Queen of the Vineyards	53.5	55.4
Sultanina	56.2	47.2
Muscat Hamburg	59.9	67.2
L.S.D.	2.53	1.48
Q	3.03	1.78
P	< 0.05	< 0.01

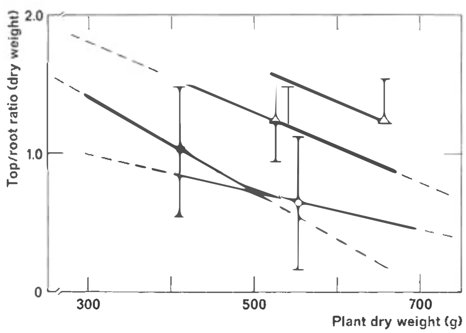

Fig. 7: The relation between top/root ratio and plant dry weight.

■	Queen of the Vineyards	$y = -0.34 \cdot 10^{-2} x + 2.44$
Δ	Sultanina	$y = -0.25 \cdot 10^{-2} x + 2.55$
o	Muscat Hamburg	$y = -0.14 \cdot 10^{-2} x + 1.40$

Vineyards were ranked inversely, depending on whether the top part or whole plant is considered. It is worth noting that the average leaf weight of Sultanina was as high as that of Muscat Hamburg (Table 2), whereas when vigor was eliminated (Table 3), the leaf weight of Sultanina was the lowest.

When top/root ratio was related to total plant dry weight (Fig. 7), the correlation for all individual plants was $r = -0.605$. The correlations for Sultanina and Muscat Hamburg were —0.731 and —0.783 respectively, while that for Queen of the Vineyards was lower, $r = -0.580$ (still significant). These correlations indicate that increase in the above-ground parts of the individual plants was followed by a relatively greater increase in root weight. However, the curves, as shown in Fig. 7, were steeper for Queen of the Vineyards and Sultanina than for Muscat Hamburg. (The difference was not significant below the 10% level.) In other words, the relative increase in root weight with vigor was the lowest in the Muscat Hamburg.

Attention should be paid to the similarity of Figs. 3 and 6, showing the relation between water efficiency and whole plant or leaf dry weight, and Fig. 7, describing the relation between top root ratio to plant dry weight. In all three figures, correlations between and within cultivars are shown and the regression line of Muscat Hamburg is always less steep than for the other two cultivars which do not differ in their angles. They differ, however, in covariance analysis, revealing a higher efficiency of the Queen of the Vineyards. It might well be that all the para-

Table 4

The relation top part dry weight and new leaf area of three grapevine cultivars

Mean top weight of plant in relation to population mean	Queen of the Vineyards		Sultanina		Muscat Hamburg	
	Plant top dry weight (g)	Mean leaf area (cm^2)	Plant top dry weight (g)	Mean leaf area (cm^2)	Plant top dry weight (g)	Mean leaf area (cm^2)
Small[1])	155.6	96.3	193.3	111.1	124.2	82.5
Large[1])	213.9	115.0	296.5	132.3	213.0	98.8
L.S.D. ($P < 0.01$)	—	16.5	—	14.6	—	15.0

[1]) For explanation see text.

Table 5

The relation between mean leaf area and water consumption per unit leaf area of three grapevine cultivars

Mean leaf size of plants in relation to population mean	Queen of the Vineyards		Sultanina		Muscat Hamburg	
	Mean leaf area (cm^2)	Water consumption ($ml \cdot dm^{-2}$)	Mean leaf area (cm^2)	Water consumption ($ml \cdot dm^{-2}$)	Mean leaf area (cm^2)	Water consumption ($ml \cdot dm^{-2}$)
Small	81.3	99.5	101.9	95.864	90.72	102.0
Large	106.6	80.1	136.0	73.8	126.8	72.2
L.S.D.	—	6.6	—	11.0	—	26.0
		$P < 0.01$		$P < 0.05$		$P < 0.01$

meters involved in these three figures, plant or leaf dry weight and top/root ratio are connected with the water use efficiency of the whole plant.

No correlation was found between dry weight of the top part or that of whole plants and the average area of one leaf. We grouped the plants of each cultivar into two categories. Plants weighing less or more than the average, by at least half the standard deviation, were separated and the corresponding average area of a single leaf was calculated (Table 4). It is shown that large plants also had large leaves, while small plants develop small leaves. The same method was employed to compare the water use efficiency of plants having large or small leaves. The efficiency of plants having larger leaves was greater in consuming less water per unit leaf area (Table 5). Thus we see that water use efficiency per unit leaf area within each cultivar was connected with the size of the leaves, which were related to vigor. This method of analysis did not enable comparison between cultivars due to the large differences in leaf area and their variation.

Photosynthesis and transpiration of single leaves measured by the gasometric method did not differ significantly (Table 6). The values were similar when calculated on either base, leaf area and leaf dry weight. It should be noted, however, that Queen of the Vineyards, which was shown earlier to be most efficient, had also the highest gas exchange values. This still indicates that the difference within and between cultivars in growth may be attributed either to translocation of assimilates or to the fact that the experimental conditions under which the measurements were taken did not reflect the situation under natural conditions.

Discussion

Vigor was found to be one of the most important factors in the water use efficiency of plants. The three cultivars investigated in the present study differed in their vigor, Sultanina being the most vigorous, then Muscat Hamburg, and Queen of the Vineyards being the weakest. This grading holds whether we relate vigor to rate of shoot growth, dry weight accumulation of whole plants or tops, as well as leaf area. This is not quite the same for top/root ratio and dry weight of leaves, since Muscat Hamburg had the lowest top/root ratio and highest leaf weight. The leaves are probably the most important factors in water use efficiency of the entire

Table 6

Net photosynthesis and transpiration of single leaves measured by gasometric methods

Cultivar	CO_2 consumption ($mm^3 \cdot dm^{-2} \cdot min^{-1}$)	CO_2 consumption ($mm^3 \cdot g^{-1} \cdot min^{-1}$)	Transpiration ($mg \cdot 10^{-3} \cdot dm^{-2} \cdot min^{-1}$)	Transpiration ($mg \cdot 10^{-3} \cdot g^{-1} \cdot min^{-1}$)
Queen of the Vineyards	83.0	107.6	22.0	32.5
Sultanina	79.0	100.0	20.0	30.3
Muscat Hamburg	76.0	92.6	19.0	25.7
S. E.	5.30	8.26	0.26	3.76

plant, since they carry out both functions, which determine the transpiration ratio, i. e. photosynthesis and transpiration. The relation of leaf area and leaf dry weight to the photosynthesis of the whole plant is not clear. During the gasometric measurements that we conducted the boundary layer resistance was minimized, while mutual interference between leaves resulting in shading and CO_2 gradients within a canopy was eliminated by exposing single leaves to direct and uniform radiation and CO_2 concentration. Some evidence of the effect of leaf thickness, leaf anatomy and other leaf qualities on the photosynthetic efficiency of grapevines was provided by Schwanitz (17) and Geisler (10). It is of interest that in the present study the leaves were found to be a positive factor in water use efficiency. An increase in leaf area as well as an increase in the average area of single leaves was connected with an increased ratio of rate of photosynthesis to transpiration, i. e. an increase in leaf area causes a relatively larger increase in photosynthesis than in transpiration.

Large leaves were associated in the present study with vigor within and between cultivars. Vigor as a characteristic for a cultivar probably depends on both genetic and agrotechnical conditions, while variation in vigor within a cultivar is due to growing conditions only. Vigor of cultivars depends largely on growing conditions and therefore grading of cultivars and probably also of species according to their efficiency of water use, is likely to differ due to growing conditions. Interaction between weather conditions and vigor may be responsible for the large differences within and between species reported in the literature (15, 17). The difference in the regression lines indicates that increasing the vigor of Muscat Hamburg (i. e. by improving agrotechnical treatment) is comparatively less beneficial than for Sultanina and Queen of the Vineyards. Thus, under conditions less conducive to vigor, Muscat Hamburg is more efficient, while under those favoring vigor, this cultivar is less efficient than Sultanina and Queen of the Vineyards. On the other hand, a comparison between Sultanina and Queen of the Vineyards shows that increasing vigor in either has a similar quantitative effect. Covariance analysis enabled comparison of individual plants with the same vigor. Queen of the Vineyards is a more efficient water user than Sultanina under conditions favoring a similar vigor for both cultivars.

The mechanism through which vigor affects the water use efficiency is not quite clear. The similarity between Figs. 3, 6 and 7 suggests that the top/root ratio is most important in determining the rate of change in water use efficiency. Top/root ratio is a cultivar characteristic probably related to translocation of assimilates. Another explanation of the effect of vigor may be connected with leaf weight and area. Increasing leaf number and leaf area results in an increase in resistance to diffusion of CO_2 and H_2O vapor per plant in units of $sec \cdot cm^{-3}$. Since transpiration is controlled by this diffusion resistance, while photosynthesis is dependent on "mesophyll resistance" as well (23), it is likely that increasing leaf area improves the photosynthesis/transpiration ratio, i. e. the water use efficiency (23).

Summary

The efficiency of water use (transpiration ratio) was investigated in various cultivars of grapevine by gravimetric and gasometric methods. Results of gravimetric measurements showed positive correlation between water use efficiency and vigor. Regression lines of the transpiration ratio on the final dry weight differed significantly in their curves and their distance from the coordinate axes. Statistical analysis showed that the quantitative effect of vigor on the water use efficiency was smaller in the cultivar Muscat Hamburg than in Sultanina and Queen of the Vine-

yards. Covariance analysis showed that Sultanina was a less efficient water user than Queen of the Vineyards for plants with the same vigor. Gasometric methods did not reveal any significant differences between the cultivars, probably due to the elimination of interference and boundary layer resistance effect.

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