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A Comparative Study of Drought and Excess-Water Tolerance in *Vitis coignetiae* and Several Table Grapes Grown in Japan

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Excess-water and drought tolerance of *Vitis coignetiae* grapevines were compared against 2 *V. vinifera* cultivars, Muscat of Alexandria and Rizamat; and 2 hybrids (*V. vinifera* × *V. labrusca*), Delaware and Kyoho. Three-year-old cutting vines of each, planted in root zone restricted beds in a plastic house, were tested under water logged and irrigation-withheld conditions starting from early and mid July, respectively. Control vines were irrigated at pF 2.2 of soil water tension. Effects of water logging were firstly observed in *V. coignetiae* vines where the basal leaves turned dark red after 12 days, and then abscised after 3 weeks. Under 2 weeks of water logged conditions, net assimilation rate (NAR) of the primary leaves decreased significantly in *V. coignetiae* and the hybrid cultivars, while there was a slight decrease in *V. vinifera* cultivars. In irrigation-withheld conditions, Kyoho leaves turned yellow 3 weeks after the onset of the treatment and then dried out 4 weeks later. Leaves of Rizamat, Delaware, and Muscat of Alexandria vines exhibited a slight color fading or leaf curling after 4 weeks of irrigation withholding, but these symptoms did not extend thereafter. Leaf NAR and transpiration rate decreased significantly in all tested vines after 10 days of irrigation withholding, though the decrease was rapid in Kyoho vines. These results indicate that *V. coignetiae* vines have a lower tolerance for water logging than other cultivars, whereas they have moderate drought tolerance.

Key words : *Vitis coignetiae*, drought tolerance, excess-water tolerance, NAR, leaf drying

Introduction

Vitis coignetiae Pulliat is a wild grape species commonly found throughout the Japanese Islands. After 1980, they were domesticated in Hiruzen Highlands for wine making. In recent years, 20–40 tons of clusters are harvested annually from 7–10 ha of vineyards. As the vineyards have been established mainly along a mountain stream called "Myoren Gawa", rainwater runs through and percolates the vineyards. Vineyards near to the river are waterlogged after heavy rains, while those located on the mountainsides are usually parched during dry summers. In Hiruzen vineyards, severe leaf withering has been observed in both rainy and dry seasons, which leads to insufficient berry ripening due to the shortage in leaf assimilation.

Berries of *V. coignetiae* accumulate high skin anthocyanin and total soluble solids (TSS) of more than 18 Brix when fully ripened[7)]. From our previous work at Hiruzen vineyards, Ueki *et al.*[8)] demonstrated that loss of sound leaves on bearing shoots negatively affects berry growth during the ripening stage.

Generally, it has been supposed that *V. coignetiae* grapevines have a higher tolerance against drought, excess-water conditions and fungi attacks than other commercial grape cultivars, because they have survived in wild conditions. However, no definite evidence has been demonstrated by scientific investigations.

In this work, we examined the drought and excess-water tolerance of *V. coignetiae* grapevines and compared these with four representative table grape cultivars under artificial experimental conditions.

Materials and Methods

Tested cultivars and experimental treatments

Own root vines of *V. coignetiae* and four different table grape cultivars were used as plant materials.

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The table grape cultivars were 2 *V. vinifera* cultivars, Muscat of Alexandria and Rizamat; and 2 hybrids of *V. vinifera* × *V. labrusca*, Delaware and Kyoho. Two-bud cuttings were taken in the early spring of 2001 and grown under plastic film cover. Fifteen vines of *V. coignetiae* and each cultivar showing average development were chosen in the early spring of 2002 and planted in three beds of 6.0 × 0.3 × 0.2 m for length, width, and depth, respectively. A root-proof sheet (Yunitika #500) was installed in each bed to prevent root movement outside of the bed. For the first bed, additional water-proof plastic sheet was installed below the root-proof sheet to simulate water logging conditions. All test vines were pruned to the 5th node. Two shoots per vine were allowed to develop upward. All clusters were removed before flowering. Irrigation, fertilization, and pest control were managed as usual. Leaf length was recorded and used for the calculation of leaf area by means of regression equation developed for *V. coignetiae* and each of the cultivars[8]. Before the start of treatment, total leaf area per vine was adjusted between 2,500 cm^2–3,500 cm^2 for the table grape cultivars and between 4,400 cm^2–4,700 cm^2 for *V. coignetiae*. Water logging treatment was started on July 2 by filling the entire first bed with tap water. The treatment was kept up till July 31 when most leaves lost their photosynthetic activity. In the second bed, drought conditions were simulated by withholding all irrigation from July 16 till August 12. Control bed, the third, was irrigated via drip irrigation tubes when soil moisture tension reached around pF 2.2.

Measurement of leaf water potential and leaf color

Sample leaves were collected from the middle part of each shoot at 10 a.m. at weekly intervals and were immediately brought to the laboratory. Water potential measurements were conducted by a pressure chamber method and leaf color values (*L*, *a*, and *b*) were recorded by a colorimeter (Nippon Denshoku, NR-3000).

Measurements of leaf photosynthesis

Photosynthetic rate and leaf stomatal conductance were measured using a portable photosynthesis analyzer (SHIMADZU, SPB-H4). Leaves of upper shoots were examined between 12 a.m.–1 p.m. under fine or cloudy day conditions. Measurements were replicated four or five times for each cultivar.

Leaf wilting and dryness

Leaf pigmentation, fading, wilting, and dryness were visually investigated every 2 or 3 days for each vine throughout the test period.

Results and Discussion

1. Effects of excess-water treatment

In the water logging treatment, first symptoms were observed in *V. coignetiae* vines after 12 days, when leaves of basal shoots exhibited a reddish color and tip dryness (Fig. 1). These symptoms extended to upper leaves, and after 3 weeks 2 vines out of 5 showed a complete dark red coloration. In Delaware vines, the back side of basal leaves turned brown 2 weeks after the start of treatment. On the other hand, no consistent differences were found between treated and control vines in leaf *L, a*, and *b* values of *V. coignetiae* vines and the other cultivars (Data not shown). Leaf water potential in treated vines became significantly higher than those in control vines 2 weeks after the treatment, although the differences were disappeared irrespective of vine species and cultivars when measured 4 weeks later (Data not shown).

Changes in photosynthetic rate after treatment are shown in Fig. 2. There were no significant differences in photosynthetic rates among control vines of *V. coignetiae* and the other cultivars. However, the effect of the water logging treatment was more remarkable in vines of *V. coignetiae* and Kyoho where photosynthetic rate declined to almost 0 after 2 weeks of treatment. A decline in photosynthetic rate was detected in Delaware and Rizamat 8 and 15 days later, respectively. Furthermore, Muscat of Alexandria photosynthetic rate was constant even after 29 days of water logged conditions.

The effects of water logging treatment on leaf

Fig. 1 Leaf pigmentation and marginal drying in *Vitis coignetiae* grapevines observed 12 days after the onset of excess-water treatment. Arrows indicate pigmented and withering leaves.

transpiration rate of *V. coignetiae* and the 4 table grape cultivars were similar to that of the photosynthetic rate (Fig. 3). Kyoho and *V. coignetiae* vines were affected more severely than the other 3 cultivars, and Muscat of Alexandria was the cultivar least affected by the water logging treatment.

2. Effects of drought treatment

Leaf wilting was first observed in Kyoho vines. Their leaves turned yellow 3 weeks from the onset of treatment and then dried out 4 weeks later. Next, the leaves of basal shoots in Rizamat vines turned yellow. In Delaware and Muscat of Alexandria vines, leaf curling occurred on the basal shoots, whereas no distinct symptoms were observed in *V. coignetiae* leaves (Fig. 4).

Leaf water potential in treated vines was significantly higher than in the control vines, irrespective of vine species and cultivars, when measured 2 weeks after the start of withholding of irrigation (Data not shown). Usually water soil deficit stress causes severe lowering of leaf water potential. The increased leaf water potential in this drought treatment might be detected by discontinuous petiole xylem water, caused by a rapid water deficit in vines, resulting in easier overflow of petiole water when applied to the pressure chamber.

Before the onset of treatment, leaf photosynthetic rate in Muscat of Alexandria recorded the highest value, followed by *V. coignetiae*, Delaware, and Rizamat, whereas Kyoho was the lowest. Irrigation withholding conditions caused a significant decrease in photosynthetic rates in all tested vines. As shown in Fig. 5, the photosynthetic rate decreased below zero after 10, 15, and 28 days in Kyoho, Delaware and Rizamat; and *V. coignetiae* and Muscat of Alexandria vines, respectively. The higher drought tolerance in *V. vinifera* grapevines, compared with those of *V. labrusca* and their hybrids, is commonly noticed in commercial vineyards. It has been reported that the degree of drought tolerance of grapevines increases as the growth stage advances[1,4]. Our test was conducted during mid summer when most leaves had already reached full mature stage. The results obtained in this experiment suggest that the highest drought tolerance in *V. coignetiae* vines must be critically significant when grapevines are suffering from severe drought conditions during spring and early summer.

Regarding the leaf transpiration rate, as displayed in Fig. 6, a rapid decrease was recorded in all vines under drought conditions. The decrease, however, was

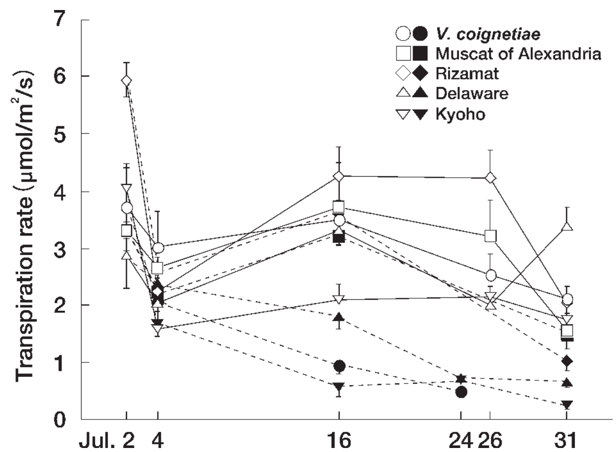

Fig. 3 Effect of excess-water treatment on leaf stomata conductivity in *V. coignetiae* and 4 table grape cultivars. Open symbols indicate untreated vines, closed symbols treated ones. Vertical bars indicate SE (n=4). The treatment started on July 2.

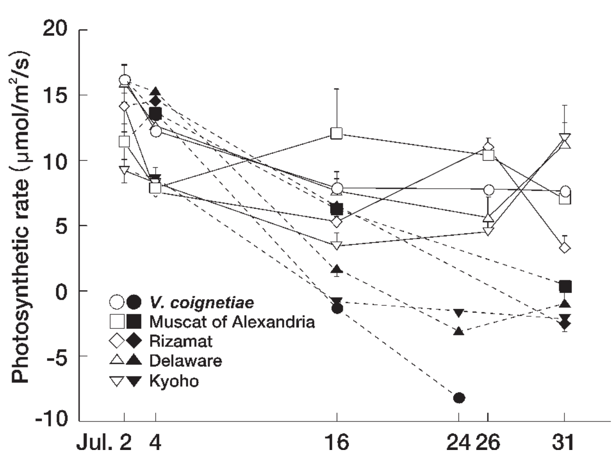

Fig. 2 Effect of excess-water treatment on leaf photosynthesis rate in *V. coignetiae* and 4 table grape cultivars. Open symbols indicate untreated vines, closed symbols treated ones. Vertical bars indicate SE (n=4). The treatment started on July 2.

Fig. 4 Leaf drying in Kyoho grapevines observed 4 weeks after withholding irrigation. Vines at the right side are *Vitis coignetiae* vines with no distinct symptoms.

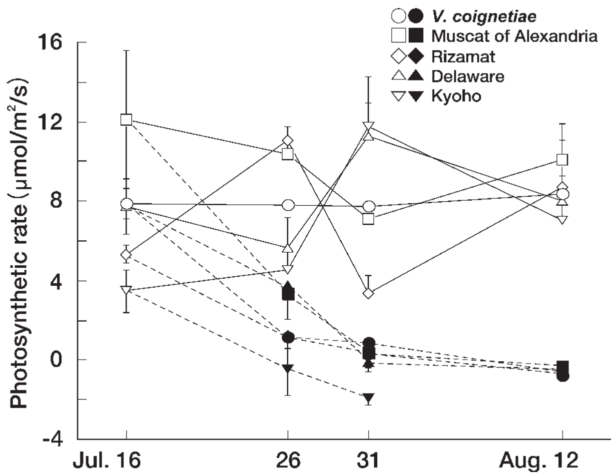

Fig. 5 Effect of irrigation withholding treatment on leaf photosynthetic rate in *V. coignetiae* and 4 table grape cultivars. Open symbols indicate untreated vines, closed symbols treated ones. Vertical bars indicate SE (n=4). The treatment started on July 16.

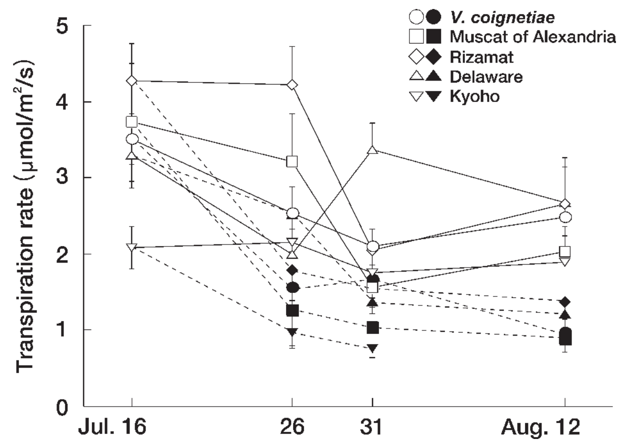

Fig. 6 Effect of irrigation withholding treatment on leaf stomata conductivity in *V. coignetiae* and 4 table grape cultivars. Open symbols indicate untreated vines, closed symbols treated ones. Vertical bars indicate SE (n=4). The treatment started on July 16.

Table 1 Effect of drought treatment on leaf color (*L* and *b* values) in *Vitis coignetiae* and 4 table grape cultivars [a)]

Grape specis and cultivar	Days after withholding irrigation								
	0	7		16		21		28	
		Treat.	Cont.	Treat.	Cont.	Treat.	Cont.	Treat.	Cont.
				L value					
V.coignetiae	39.8	38.9	35.7	38.8	36.4	36.0	36.3	34.9	31.4
V. vinifera									
Muscat of Alexandria	42.3	38.5	38.5	38.6	35.7	35.4	36.0	30.8	34.9
Rizamat	37.6	42.1	39.5	44.9	42.0	46.4	43.3	41.4*[b)]	36.2
V. vinifera × *V. labrusca*									
Delaware	39.9	35.0	43.8	38.0	35.9	38.6	37.9	32.3	31.8
Kyoho	37.8	44.6	41.1	45.6	43.4	50.5*	44.7	61.6	37.1
				b value					
V.coignetiae	19.4	25.4	18.2	22.5	21.6	26.1	23.7	14.8	14.1
V. vinifera									
Muscat of Alexandria	26.5	22.7	22.4	20.9	17.6	20.9	19.2	13.1	12.3
Rizamat	22.7	23.1	25.6	25.7	25.6	28.6	27.4	19.8*	16.7
V. vinifera × *V. labrusca*									
Delaware	25.5	22.4	29.1	22.2	23.7	22.6	22.6	13.4	13.1
Kyoho	21.7	28.2	26.5	28.3	28.0	33.6*	28.6	25.5*	17.4

[a)]Drought treatment was conducted by withholding all irrigation on August 16.
[b)]*indicates that the value is significantly different ($p = 0.05$) from the value in Cont. by T-test (n = 4).

remarkable in Kyoho and Delaware vines.

Effects of the drought treatment on leaf color values, *L*, *a*, and *b,* were not apparent in *V. coignetiae*, *V. vinifera* cultivars, and Delaware vines. However, Kyoho vines showed an increase in *L* and *b* values after 3 weeks of treatment (Table 1). Such elevated values indicate that the leaf color turned yellowish which might be caused by a loss in chlorophyll as a result of dryness.

Conclusion

Nakagawa[6)] and Horiuchi[2)] have investigated the geographic distribution and morphological characteristics of Japanese wild grapes, including *V. coignetiae*, as well as their cold tolerance. In their works, *V. coignetiae* vines exhibited severe cold injury when the excised stems were treated at −13°C, which was a similar response to an American variety, Campbell

Early. Mullins *et al.*[5] noted that *V. coignetiae* grapevines have a strong resemblance to *V. labrusca* vines that can tolerate lower temperature conditions. However, drought and excess-water tolerance of *V. coignetiae* have not been evaluated anywhere. In this experiment, it has been demonstrated that this grape species has a low tolerance for excess-water conditions. These results correspond to the cultivation experiences of Hiruzen growers who have managed riverside *V. labrusca* vineyards. Vineyards of *V. coignetiae* grapevines should be planted in soil which drains well. On the other hand, withholding irrigation tests revealed that *V. coignetiae* grapevines have moderate or rather strong drought tolerance. However, the test were carried out on young non-bearing vines. The effect of crop loading on leaf drying in fruit trees during a dry summer is generally understood[3]. It would be valuable to test the effect of drought treatment using mature bearing grapevines.

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耐乾・耐湿性に関するヤマブドウ（*Vitis coignetiae* Pulliat）と生食用ブドウ品種の比較

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ヤマブドウ樹の耐湿，耐乾性を知るために，一般的に栽培されている4種の生食ブドウ品種，マスカット・オブ・アレキサンドリア，リザマート（*V. vinifera*）及びデラウエア，巨峰（*V. vinifera* と *V. labrusca* との雑種）との比較を行った．実験は，根域制限ベッドに植えた3年生挿し木個体（無着果）を用い，7月上旬，中旬から水没，灌水停止の処理を行って，葉の異常や葉色の変化，光合成・蒸散速度を測定した．水没処理を行った後の葉色の変化はヤマブドウで最初に見られ，約2週間後に基部の葉が赤色になり，やがて落葉した．処理2週間後にはヤマブドウと雑種2品種の葉の光合成が低下したが，*vinifera* の2品種では変化がなかった．灌水停止処理の場合は，巨峰の葉色の変化が最も早く，4週間後には枯死した．その他の生食用品種でも葉の退色や葉巻が見られたが，ヤマブドウでは著しい兆候は見られなかった．葉の光合成・蒸散速度は，灌水停止後10日目にいずれの個体でも有意に低下したが，その低下は巨峰で最も著しかった．以上の結果から，ヤマブドウは耐乾性は比較的強いが，耐湿性は劣ることが明らかになった．