

Influence of the twospotted spider mite, *Tetranychus urticae*, on the gas exchange of Pinot noir grapevine leaves

by

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S u m m a r y : The effect of feeding damage by the twospotted spider mite (*Tetranychus urticae* KOCH; Acari: Tetranychidae) on the gas exchange of grapevine leaves (*Vitis vinifera* L.; cv. Pinot noir) was investigated. In addition, the influence of some pesticides was studied. A significant reduction of the net CO₂ assimilation, transpiration as well as stomatal and mesophyll conductance with increasing mite feeding damage were observed. At 6000 mite-days per leaf the 3rd and 9th main leaves (from the base) showed an average reduction in net CO₂ assimilation of 52.2 % and 48.4 %, respectively, while the 6th leaf showed a reduction of only 21.3 %. The response of grapevine photosynthesis to mite feeding seems to depend not only on mite density and duration of feeding, but also on the phenological stage of the plant. In fact, at veraison the vines showed increased tolerance to mite feeding compared with other phenological stages.

At mite infestation levels of 6000 mite-days, leaves infested with *T. urticae* showed, as compared to uninjured leaves, an average reduction in transpiration rate of 14.4 % to 40.8 %, depending on the leaf position.

The acaricides Tetradifon and Fenbutatin-oxide and the fungicide Folpet combined with Penconazol showed no effect on the gas exchange parameters.

Key words : Acari, spider mites, *Tetranychus urticae*, pesticide, damage, photosynthesis, transpiration, stomatal conductance, mesophyll conductance, *Vitis vinifera*, grapevine.

Introduction

The relationship between mite density and grape performance was, except for the works of LAING *et al.* (1972) and WELTER *et al.* (1989 b), mostly studied on a qualitative basis without giving an exact indication of the mite-load (SCHROPP *et al.*, 1982; ARIAS and NIETO 1983; McNALLY and FARNHAM 1985; BAILLOD *et al.* 1989). This leads to the fact that the economic injury levels actually used for the two most widespread mite species in Europe, *Panonychus ulmi* KOCH and *Tetranychus urticae* KOCH, are based on empirical estimations rather than on quantitative data (BOLLER and REMUND 1983). A review of the literature shows that, in contrast to other crops such as strawberry (POSKUTA *et al.* 1975; SANCES *et al.* 1979 a, 1979 b, 1981, 1982), apple (GOLIK 1975; HALL and FERREE 1975; FERREE and HALL 1980; BEERS and HULL 1987; CAMPBELL and MARINI 1990; CAMPBELL *et al.* 1990; MOBLEY and MARINI 1990) or citrus (HARE and YOUNGMAN 1987; HARE *et al.* 1989), there is only scarce information on the impact of mites on grapevine physiology. WELTER *et al.* (1989 a) found a linear decrease of the photosynthetic rate of grapevine leaves with an increase of *Tetranychus pacificus* MCGREGOR or *Eotetranychus willametti* MCGREGOR feeding damage. RILLING and DURING (1990) studying the histological and physiological effects of *Panonychus ulmi* KOCH on grapevine also found reduced photosynthesis with increasing mite damage. To our knowledge, there are no studies on the influence of *T. urticae* on the gas exchange of grapevine leaves.

In this investigation, the effect of *T. urticae* on the gas exchange rates of grapevine leaves was examined with a view to quantifying the physiological response of these plant organs to mite feeding. To ensure that the results obtained were not influenced by the pesticides used in the experiments, pesticide impact on gas exchange was also investigated.

Material and methods

Gas exchange measurements were performed using a portable infrared gas analyser system LCA-2 from ADC (Analytical Development Co. Ltd., England). Net photosynthesis (A , $\mu\text{mol CO}_2 \text{ m}^{-2} \cdot \text{s}^{-1}$), transpiration (E , $\text{mmol H}_2\text{O m}^{-2} \cdot \text{s}^{-1}$), stomatal conductance to CO_2 transfer (g_s , $\text{mmol CO}_2 \text{ m}^{-2} \cdot \text{s}^{-1}$) and intercellular CO_2 partial pressures (p_i , Pa) were calculated using the built-in equations of the program version 3.3 of the data-logger DL2 (Analytical Development Co. Ltd., England). Mesophyll conductance to CO_2 transfer (g_m , $\text{mmol CO}_2 \text{ m}^{-2} \cdot \text{s}^{-1}$) was computed using the values recorded by the data-logger for p_i and A as follows:

$$A = \frac{p_i - p_c}{r_m}; \quad g_m = \frac{1}{r_m}$$

where: A = net photosynthesis, p_i = intercellular CO_2 partial pressures, p_c = CO_2 partial pressure at site of carboxylation, r_m = mesophyll resistance, g_m = mesophyll conductance. Assuming that the CO_2 partial pressure at the site of carboxylation (c_c) is zero, the carboxylation resistance is implemented in the estimate of the mesophyll resistance r_m (JARVIS 1971).

The influence of the pesticides on gas exchange processes was investigated on two-year old potted Pinot noir grapevines (clone 2/45 grafted on 8B rootstock) in a growth chamber ($30^\circ\text{C}/18^\circ\text{C}$ day/night temperature, 60 % r.h. and a photoperiod of L16:D8 with $600 \mu\text{mol PAR m}^{-2} \cdot \text{s}^{-1}$ light intensity measured on the leaf where gas exchange was recorded). The plants were grown in 5-litre pots (buried in an open field until the beginning of the experiment) and bore no fruit. One shoot per plant was allowed to grow and was topped to 10 nodes. The following pesticides were tested: the acaricides Tetradifon (Remanex, Burri) at 0.2 % and Fenbutatin-oxide (Torque fluid, Agroplant) at 0.1 %, and the fungicides Folpet (Phaltan 80, Plüss-Staufer) at 0.125 % combined with Penconazol (Topas Vino, Ciba-Geigy) at 0.025 %. The control plants were sprayed with water. Application was done with a hand sprayer until run-off. Each treatment was replicated 6 times within a randomised complete block design. The gas exchange measurements were carried out in the above mentioned environmental conditions between 9.00 and 10.00 h on the 10th main leaf (from the base) before treatment, 1 h and 1, 3, 8 and 14 d after treatment.

The experiment with *T. urticae* was performed in Wädenswil (Switzerland) in 1989 on 3-year-old bearing vines, cv. Pinot noir (clone 2/45) on 5C rootstock, planted in 40-litre pots. One shoot per vine was allowed to grow and was topped to 12 nodes. The plants were artificially infested with *T. urticae*. The mites were reared on bean plants (*Phaseolus vulgaris*) at 27°C and 70 % r.h. in a growth chamber. The infestation was performed at the 3-leaf-stage (17.5.89) and at the 7-leaf-stage (23.5.89) by placing one or more infested bean leaves on all expanded grapevine leaves. After a few minutes the mites started to migrate to the grape leaf. The *T. urticae* population densities (number of mobile mites per leaf) were recorded non-destructively every fortnight by using a magnification lens. Both the upper and lower leaf surfaces of the 3rd, 6th and 9th main leaves (from the shoot base) were checked. Mite load was expressed as mite-days per leaf¹⁾ (HOYT *et al.* 1979). Gas exchange measurements were performed on 24 infested and 8 control plants at seven different phenological stages of the grapevine on the same leaves where mite density was being recorded (Table). The measurements were carried out between 9.00 and 11.30 h (2 h maximum measurement time per d) under fully light-saturated conditions ($> 1500 \mu\text{mol m}^{-2} \cdot \text{s}^{-1}$). The control plants were regularly sprayed with one of the above mentioned acaricides to keep them

¹⁾ one mite-day (mite-d) corresponds to one mite feeding for one day.

mite-free. All other cultural practices (fertilisation, irrigation, weed control, disease control and green pruning) were the same for all the treatments.

Statistical analysis. The results from the pesticide experiment were subjected to analysis of variance and the Duncan's multiple range test was used to compare means. The relationships between mite feeding damage (mite-days per leaf) and the gas exchange parameters were tested by regression analysis. To analyse the effect of mites on gas exchange over the entire season the data were expressed as a percentage (mean of the control = 1) for each measurement date. This was necessary to account for random variation in gas exchange due to different environmental conditions (KRIEDEMANN 1977) and to different leaf age and source-sink relationships at different phenological stages of the plant at different measurement dates (KRIEDEMANN *et al.* 1970; SCHULTZ 1989; CANDOLFI-VASCONCELOS and KOBLET 1991).

Table
Gas exchange measurement dates on "Pinot noir" grapevine leaves in the mite experiment.

3 rd leaf		6 th leaf		9 th leaf	
Date	Phenological stage ¹⁾	Date	Phenological stage	Date	Phenological stage
26.5.89	15				
9.6.89	17				
15.6.89	19			14.6.89	19
26.6.89	26	26.6.89	26		
13.7.89	33				
20.7.89	34	20.7.89	34		
30.8.89	36-37	30.8.89	36-37	30.8.89	36-37

¹⁾ As described by EICHHORN and LORENZ (1977).

Results and discussion

Influence of pesticides on gas exchange. The acaricides Tetradifon and Fenbutatin-oxide had no influence neither on photosynthesis nor on transpiration over the 14-d period (data not shown). The fungicide Folpet combined with Penconazol had no influence on gas exchange of grapevine leaves either. LAPRÉ *et al.* (1982) and JONES *et al.* (1983) studied the influence of the compound Fenbutatin-oxide in gas exchange of strawberry and orange leaves, respectively, and obtained similar results. The agrochemicals Folpet and Tetradifon showed also no influence on gas exchange of apple leaves (AYERS and BARDEN 1975). Since these pesticides had no obvious influence on plant physiology, measuring the gas exchange in the treated vineyards was possible without taking any special precautions.

Influence of *T. urticae* on gas exchange. All measured leaves (3rd, 6th, 9th leaf) showed a similar response to mite feeding despite their different age. For this reason only the data obtained from the measurements of the 3rd leaf will be shown. A significant reduction of the net CO₂ assimilation, transpiration as well as stomatal and mesophyll conductance with increasing mite-load were observed (Fig. 1). The 6th leaf showed a less sensitive reaction to mite feeding than the other leaves measured. At 6000 mite-d the 3rd and 9th leaves showed an average reduction in net CO₂ assimilation of 52.2 % and 48.4 %, respectively (values predicted by the regres-

sion functions), while the 6th leaf showed a reduction of only 21.3 %. The proximity and the position of the 6th leaf in relation to the fruit (the fruit was usually located at

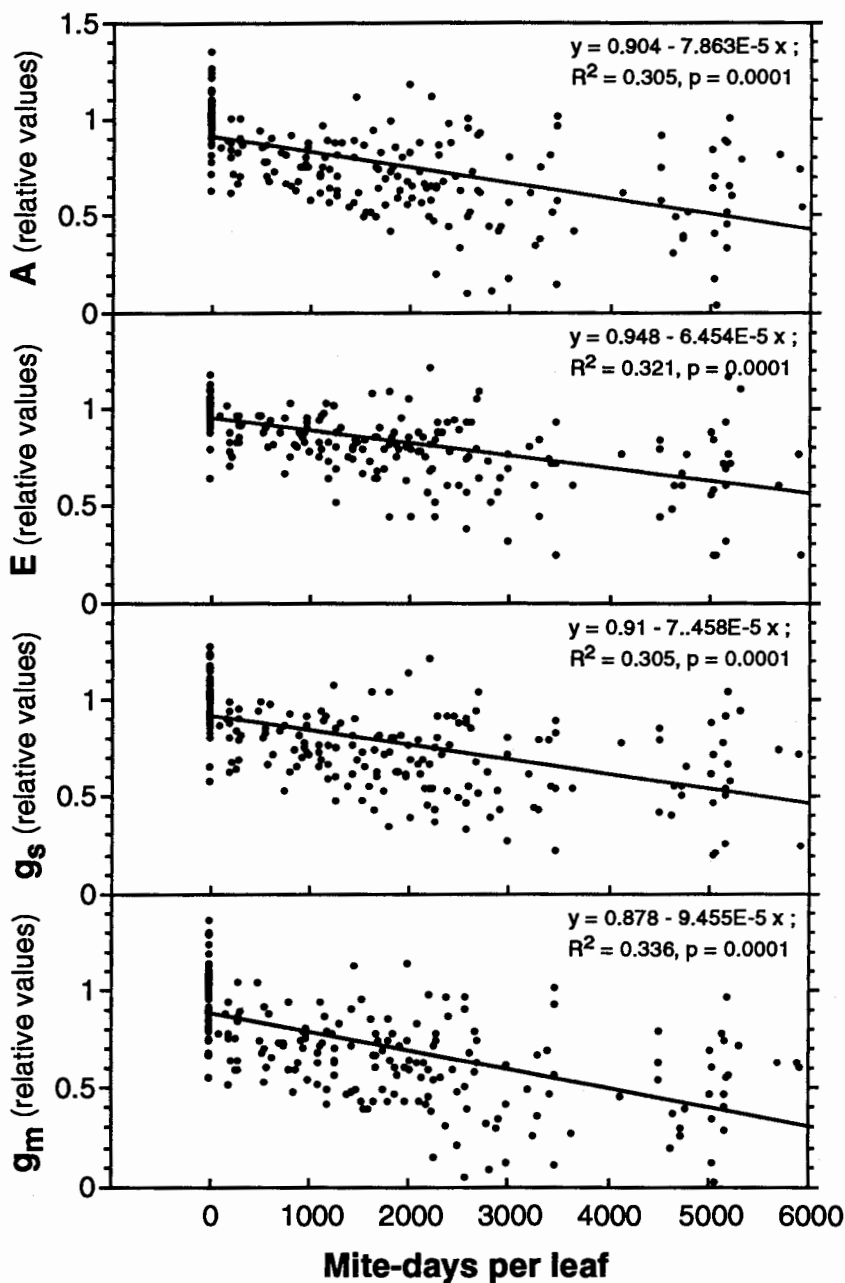


Fig. 1: Relationship between *Tetranychus urticae* mite-load (mite-d/leaf) and relative photosynthesis (A), relative transpiration (E), relative stomatal conductance (g_s), and relative mesophyll conductance (g_m) of the 3rd main leaf (from the shoot base) of Pinot noir grapevine. Plotted are all the relative values measured at several phenological stages over the season.

node five) may explain this less sensitive reaction. In fact the cluster obtains the assimilates mostly from the proximate leaves on its own side of the shoot (KOBLET 1969; MOTOMURA 1990), and it is known that demand for assimilates can control the rate of photosynthesis (KRIEDEMANN *et al.* 1976). Apparently, the decrease of the net assimilation rate by mite feeding was limited both by the CO_2 entry through the stomata (g_s) and by its transport through the mesophyll cells and fixation in the chloroplasts (g_m) (Fig. 1).

The response of grapevine photosynthesis to mite feeding seems to depend not only on mite density and duration of feeding but also on the phenological stage of the plant. In fact, as shown in Fig. 2, the impact of mite feeding on the photosynthetic performance at the same infestation level differed at different phenological stages. A comparison of the net assimilation rate of the 3rd leaf at a mite infestation level of 5000 mite-d at the end of bloom (stage 26 as described by EICHHORN and LORENZ 1977)

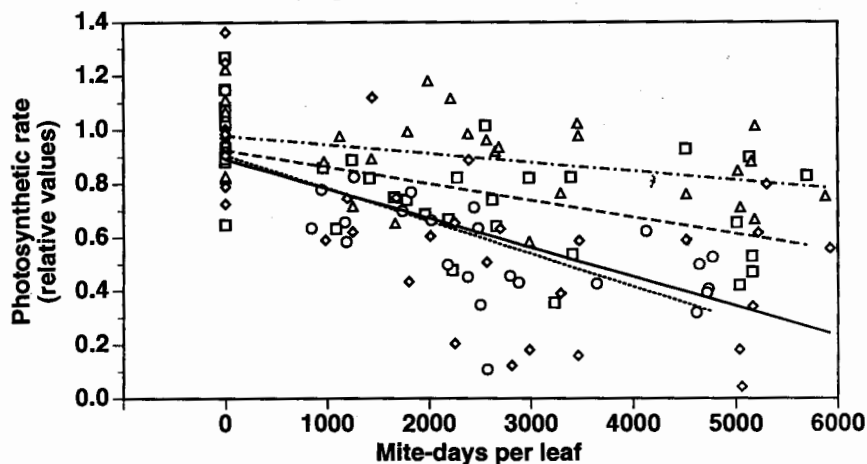


Fig. 2: Relationship between *Tetranychus urticae* mite-load (mite-d/leaf) and rate of photosynthesis (relative values) on the 3rd main leaf (from the shoot base) of Pinot noir grapevine at 4 different phenological stages: stage 26 (26.6.89): O, --- measured values and regression line ($R^2 = 0.636$, $p = 0.0001$); stage 33 (13.7.89): □, --- measured values and regression line ($R^2 = 0.287$, $p = 0.0016$); stage 34 (20.7.89): Δ, --- measured values and regression line ($R^2 = 0.149$, $p = 0.0293$); stage 36—37 (30.8.89): ◇, — measured values and regression line ($R^2 = 0.395$, $p = 0.0001$).

showed a 67.5 % reduction as compared to the control (values calculated with the regression function), while at the beginning of berry touch (stage 33) it was 33.8 % and shortly before veraison (stage 34) the reduction was only 16.8 %. During ripening (stage 36—37) the sensitivity to mite feeding was again higher, showing a 61.4 % decrease of the net assimilation at the above mentioned mite-load. A similar trend was observed with the 6th leaf (data not shown); while after bloom (stage 26) the reduction of the net assimilation caused by mite feeding amounted to 26.7 % at 5000 mite-d, shortly before veraison (stage 34) reduction was only 13.9 % and during ripening (stage 36—37) it was 20.6 %. In contrast to apple (AVERY and BRIGGS 1968) or lima beans (MARTENS and TRUMBLE 1987), grapevine leaves do not have the ability to regenerate the tissue destroyed by mite feeding (RILLING and DÜRING 1990). The leaf cells that are left intact by the mites may increase their photosynthetic rate in response to sink demand (KRIEDEMANN *et al.* 1976) which varies along the season (HALE and WEAVER 1962; KOBLET 1969).

WELTER *et al.* (1989 a) investigated the influence of the mite species *T. pacificus* and *E. willametti* on grapevine photosynthesis. They found also a linear decrease of net

assimilation with increasing mite feeding. The reduction in the photosynthetic rate caused by these two mite species was more pronounced than that measured for *T. urticae* in our study: *E. willametti* feeding on Zinfandel grapevines caused a reduction of 67.6 % at 6000 mite-d and *T. pacificus* feeding on Thompson Seedless leaves reduced photosynthesis by 86.5 % at the same mite infestation. As mentioned above, in our experiment the average reduction of net assimilation caused by *T. urticae* feeding (6000 mite-d) on Pinot noir was between 21.3 % and 52.2 %, depending on the leaf position. However, a direct comparison is difficult because the phenological stage of the vine, measurement data and exact position of the sampled leaves are not indicated in WELTER's work. We can also not conclude that Pinot noir is more tolerant to mite feeding than the other varieties. A comparison with the data obtained by RILLING and DURING (1990) who found a decrease of assimilation with increasing *P. ulmi* damage on grapevine, is not possible either, because these authors did not relate their damage index (degree of leaf discoloration) to mite density.

In comparison to other crops such as strawberry (SANCES *et al.* 1979 b), peppermint (DE ANGELIS *et al.* 1983), peach (MIZELL *et al.* 1986) or apple (FERREE and HALL 1980; MOBLEY and MARINI 1990), the grapevine seems to be more tolerant to spider mite feeding damage. In fact, in all these crops a reduction of net assimilation due to *T. urticae* feeding was evident at much lower mite loads.

According to SANCES *et al.* (1979 a) more stomata are completely or partly closed on mite-infested leaves compared to non-infested ones. This led in our experiments to a reduction in stomatal conductance and consequently to a decrease of the transpiration rate (Fig. 1). The highest average decrease of the transpiration rate compared to the control plants was 40.8 % (values predicted by the regression function) at 6000 mite-d measured on the 3rd leaf (Fig. 1). At the same mite load the 6th leaf showed an average reduction on the transpiration rate of 14.4 % and the 9th leaf of 26.2 %. A decrease of transpiration in mite injured grapevine leaves was also reported by RILLING and DURING (1990) for *P. ulmi* and by WELTER *et al.* (1989a) for *T. pacificus* and *E. willametti*. In other crops, such as peach and apple (MIZELL *et al.* 1986), strawberry (SANCES *et al.* 1979 a) or peppermint (DE ANGELIS *et al.* 1982), transpiration was also reduced by *T. urticae* feeding.

The higher tolerance to mite feeding damage recorded in the leaves near the clusters and during veraison, shows that the grapevine leaves can adapt assimilate production to the demand even when they are damaged. As already observed by CANDOLFI-VASCONCELOS and KOBLET (1991) this great capacity of grapevine to compensate for stress has to be taken into account in the elaboration of economic injury levels for pests.

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