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Ozone Sensitivity of Grapevine (*Vitis vinifera* L.): Evidence for a Memory Effect in a Perennial Crop Plant?

By

G. SOJA[1)] M. EID [1)], H. GANGL[2)] & H. REDL [3)]

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Summary

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Grapevine plants (cv. Welschriesling), cultivated in 50 l-containers, were exposed to different levels of ozone in open top-chambers. Ozone levels equivalent to ambient air did not affect grape yield significantly. Based on treatments with four ozone levels, for a grape yield reduction of 10 % an ozone critical level of 27 ppm-h (AOT40) was calculated. Visual ozone effects were characterized by enhanced senescence of the leaves. The loss of green leaf area in ozone-fumigated plants caused severe reductions of carbohydrate import into the grapes. The degree of reduction was different in two consecutive year: in the first year of ozone exposure, the critical level for a 10 % reduction of monosaccharide yield in the grapes was 21 ppm-h (AOT40), whereas in the second year the critical level decreased to 11.5 ppm-h. Also measurements of chlorophyll fluorescence revealed a higher susceptibility to ozone in the second fumigation year. This increased sensitivity in consecutive years with high ozone doses could indicate a memory effect for the ozone dose in the previous year. But further experiments will be necessary to rule out other possible causes (e.g. interactions of sink strength and the size of the assimilate pool).

[1)] Research Centre Seibersdorf, Dept. Agricultural Research, A-2444 Seibersdorf, Austria. Fax: +43 2254 780 3653; e-mail: soja@zdfzs.arcs.ac.at

[2)] Bundesamt für Weinbau, Neusiedler Straße 55, A-7000 Eisenstadt.

[3)] Universität für Bodenkultur, Institut für Pflanzenschutz, Gregor Mendel-Str. 33, A-1180 Wien.

Introduction

Crop plants, forest trees and species of natural vegetation are known to react sensitively to elevated concentrations of ozone. It has been shown that ambient photooxidative stress during summer in Europe is high enough to decrease significantly the yield of sensitive crops, e.g. wheat, significantly. These results have led to the definition of Critical Levels for ozone which have the meaning of thresholds for significant yield reductions (FUHRER & ACHERMANN 1994). Recently, an ozone dose of 3 ppm-h has been proposed as the critical level for a 5 % grain yield reduction of wheat (KÄRENLAMPI & SKÄRBY 1996).

About ozone effects on perennial crop plants (e.g. fruit trees, vines) much less is known than about ozone sensitivity of annual crops. Fumigation experiments with grapevines are rare; a few studies have been performed with vegetative plants (SHERTZ & al. 1980) for a short fumigation time with unrealistic high pollutant concentrations. It is also known that grape quality is mainly influenced by the photosynthetic capacity of the leaves and assimilate partitioning in the plant (HUNTER & al. 1994, EDSON & al. 1995 a,b). On the other hand, enhanced senescence of the leaves is one of the dominant effects of ozone exposure (SOJA & SOJA 1995, PÄÄKKÖNEN & al. 1995). Also in apple as another perennial crop plant exposure to ozone accelerated autumn leaf fall (WILTSHIRE & al. 1993).

This paper presents results of two years of experiments that were designed to quantify dose-response-relationships between ozone dose and grape yield, grape quality and chlorophyll fluorescence.

Material and Methods

Vine plants (*Vitis vinifera* cv. Welschriesling) were pre-cultivated for two years under ambient ozone concentrations in 50 l-containers. When the plants were three years old, fumigations started in the open-top chambers (= first fumigation year, 1994).

Open-top chambers were built according to the Heagle-type. Air exchange rate was 2 chamber volumes per minute. The chambers had a frustrum and a roof, so all plants were irrigated artificially with the same amount of tap water.

Eleven plants were placed in each chamber, with two chambers per treatment. In this experimental setup four ozone levels (= four treatments) could be compared. Chambers with filtered air were ventilated with air having passed through carbon filters (Akolit C, Delbag). Ozone for the fumigated treatments was generated from pure oxygen by silent discharge in an ozone generator (Fischer 502). Ozone additions were held constant at 25 ppb and 50 ppb above ambient concentrations for 8 $h.d^{-1}$ at 5 days per week. Ozone fumigations started in mid May (about two weeks before flowering) and lasted till two weeks after grape harvest.

Grapes were harvested at full maturity. Juice was pressed from all the grapes and aliquots were conserved for chemical analyses immediately after pressing. Mono- and di-saccharides were HPLC-analysed according to CLAIRE & al. 1988. Fast kinetics of chlorophyll fluorescence were measured with a Hansatech Plant Efficiency Analyser (Hansatech Instruments, King's Lynn, Norfolk, England).

Results and Discussion

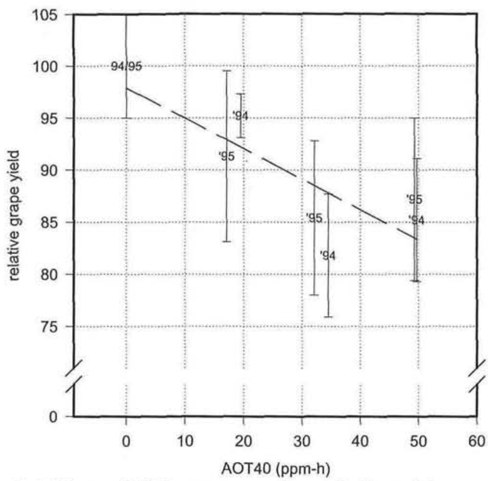

Fig. 1. Effects of different ozone doses (indicated in ppm-h of AOT40) on grape yield (fresh mass) of grapevines cv. Welschriesling. Results of two individual years (indicated as '94 and '95) are shown ± s.d.. Yield of carbon-filtered chambers is 100 % relative yield for each year. Dose-response is indicated by the regression line (dashed).

Ambient levels of ozone had no significant effects on grape yield. Only when ozone was added to ambient air, yield decreases became significant (Fig. 1). Due to unchanged water contents of the grapes, fresh and dry mass yields were similarly reduced. Weights per grape remained unaffected (results not shown). Based on a linear regression, the Critical Level for a 10% yield reduction was about 27 ppm-h. The results would be similar, when the Critical Levels were calculated separately for both years. The actual ozone doses in ambient air usually are smaller than this Critical Level; therefore it can be concluded that "Welschriesling" grapevines will not suffer ozone-induced yield losses under Middle-European conditions.

The situation is different concerning the carbohydrate concentrations of the grapes and the total sugar yield per plant. In Fig. 2a it is shown that in the first year of ozone exposure the ozone-induced decrease of monosaccharides in the grapes was only slightly higher than the decrease of total grape yield. But in the second year of exposure (Fig. 2b) this decrease in carbohydrate storage was considerably more pronounced than the corresponding yield depression. Fructose and glucose exhibited the same tendencies, but no sucrose could be detected in the grape juice. This effect of impaired carbohydrate translocation to the grapes, being more pronounced in the second than in the first fumigation year, led to a reduction of sugar concentrations by 60 % when the same ozone dose had affected yield only by 15 %.

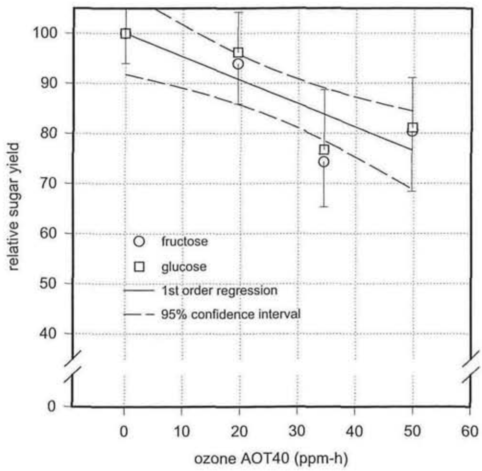

Fig. 2a. Dose-response curve for the effect of ozone dose on the absolute amount of monosaccharides in the grapes after the first fumigation period in 1994. Symbols are means ± s.d.

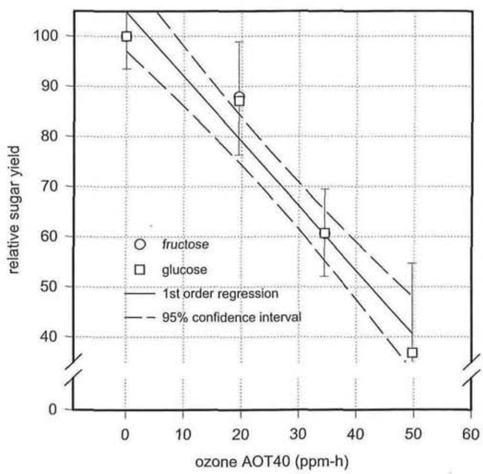

Fig. 2b. As in Fig. 2a, but after the second fumigation period in 1995. Mind the difference in the slope of the regression lines of Fig. 2a and 2b.

At the moment, two interpretations for these differences in ozone sensitivity between both experimental years seem to be possible.

a) high ozone doses in one year made the plants more susceptible to similar ozone doses in the following year (memory-effect, MÜLLER & al. 1996)

b) in years with higher grape yields (= higher sink strength for assimilates, as it was the case in the second fumigation year; 100 % = 2630 g/plant) the ozone-induced lack of assimilates affects grape sugar concentration more than in year with lower yields (first fumigation year; 100 % = 900 g/plant).

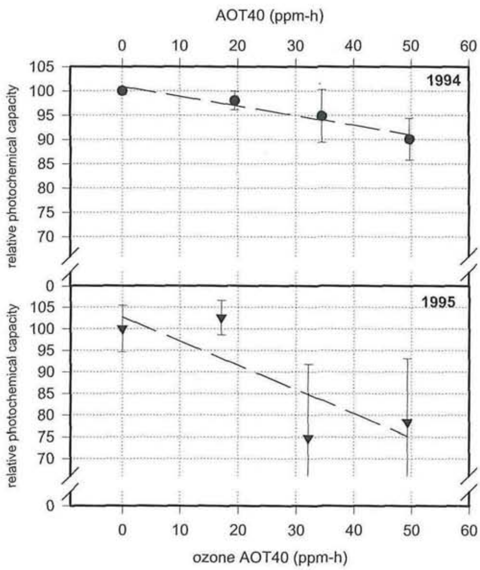

Fig. 3. Dose-response curve for photochemical capacity (F_v/F_m calculated from fast kinetics of chlorophyll fluorescence) and ozone dose. Measurements were made on the seventh node three weeks before grape harvest. Symbols are means ± s.d.

One of the reasons for the reduced assimilate import into the grapes became visually evident: fumigated plants experienced enhanced leaf senescence, leading to reduced photosynthetically active green leaf area (pictures not shown). Only in rare cases necrotic stipples, as observed by TIEDEMANN & HERRMANN 1992, appeared as a consequence of ozone exposure. The senescence effect was more pronounced in the second than in the first fumigation year. For quantifying this effect, we measured fast kinetics of chlorophyll fluorescence at defined leaf positions. Chlorophyll fluorescence showed similar differences between both years: the same leaf positions, having accumulated similar ozone doses in both years, showed more significant reductions of photochemical capacity in the second than in the first year (Fig. 3). The decreases observed in photochemical capacity, determined as the ratio F_v/F_m, were mainly due to decreases in maximum fluorescence. The chlorophyll fluorescence measurements showed similar tendencies as the onset of leaf senescence that could be visually observed only three weeks later. But carbohydrate import and photochemical parameters did not always show full agreement: in 1995 the plants exposed to ambient air (AOT40: 19 ppm-h) experienced a significant reduction of carbohydrate import into the grapes (Fig. 2b), but at neither leaf position this treatment exhibited similar effects in chlorophyll fluorescence. It is concluded that under moderate ozone stress other impairments of photosynthesis that cannot be easily recognized with the fast kinetics of chlorophyll fluorescence cause a reduction of the assimilate pool.

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References

CLAIRE A., VERRIER E. & NTONGA MIMBÉ J. 1988. HPLC analysis of the main soluble sugars in the twining shoots of *Ipomoea porpurea*. Determination of glucose, fructose, sucrose and starch content. - C. R. Acad. Sci. Paris 307 sér. III: 735-740.

EDSON C. E., HOWELL G.S. & FLORE J.A. 1995a. Influence of crop load on photosynthesis and dry matter partitioning of Seyval grapevines. 2. Seasonal changes in single leaf and whole vine photosynthesis. - Amer. J. Enol. Viticult. 46: 469-477.

— , — & — 1995b. Influence of crop load on photosynthesis and dry matter partitioning of Seyval grapevines. 3. Seasonal changes in dry matter partitioning, vine morphology, yield, and fruit composition.- Amer. J. Enol. Viticult. 46: 478 - 485.

FUHRER J. & ACHERMANN B. 1994. Critical Levels for Ozone. - Schriftenreihe der FAC Bern-Liebefeld 16, 328 p.

HUNTER J.J., SKRIVAN R. & RUFFNER H.P. 1994. Diurnal and seasonal physiological changes in leaves of *Vitis vinifera* L.: CO_2 assimilation rates, sugar levels and sucrolytic enzyme activity. - Vitis 33, 189-195.

KÄRENLAMPI L. & SKÄRBY L. 1996. Critical Levels for ozone in Europe: Testing and finalizing the concepts. UN-ECE Workshop Report. - University of Kuopio, 363 p.

MÜLLER M., TAUSZ M. & GRILL D. 1996. The classification of chromosomal aberrations - a method for the assessment of various kinds of environmental stress (1989 - 1995). - In: KNOFLACHER M., SCHNEIDER J. & SOJA G. (eds.), Exceedance of critical loads and levels. Umweltbundesamt Conference Papers 15, 195-203. - Vienna.

PÄÄKKÖNEN E., HOLOPAINEN T. & KÄRENLAMPI L. 1995. Ageing-related anatomical and ultrastructural changes in leaves of birch (*Betula pendula* Roth) clones as affected by low ozone exposure. - Ann. Bot. 75, 285-294.

SHERTZ R.D., KENDER W.D. & MUSSELMAN R.D. 1980. Effects of ozone and sulfur dioxide on grapevines. - Scient. Hort. 13, 37-45.

SOJA G. & SOJA A.M. 1995. Ozone effects on dry matter partitioning and chlorophyll fluorescence during plant development of wheat. - Water, Air and Soil Pollution 85: 1461-1466.

TIEDEMANN A.V. & HERRMANN J.V. 1992. First record of grapevine oxidant stipple in Germany and effects of field treatments with ethylendiurea (EDU) and benomyl on the disease. - Z. Pfl.Krankh. Pfl.Schutz 99: 533-541.

WILTSHIRE J.J.J., WRIGHT C.J., UNSWORTH M.H. & CRAIGON J. 1993. The effect of ozone episodes on autumn leaf fall in apple. - New Phytol. 124: 433-437.