Effects of CO_2 at 1-MCP Treated Tomato on the Vine

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Abstract

Elevated CO_2 can inhibit ethylene effects. The mechanism of this inhibition is not exactly known. It was investigated whether competition with ethylene at the receptor binding-site is involved. The receptor binding-site was blocked by 1-methylcyclopropene (1-MCP). In this case CO_2 can not have an effect via ethylene perception. The influence of 10 kPa CO_2 was studied at 1-MCP treated tomato on the vine (cv. 'Tradiro') during storage. The ethylene production rate of tomato on the vine at 20 °C was inhibited by 1-MCP and by CO_2. After 1-MCP pre-treatment, CO_2 still inhibited ethylene production. It can be concluded that the effect of CO_2 on ethylene action is not (always) directed via inhibition of ethylene binding at the receptor site. It was also investigated whether CO_2 can inhibit fruit abscission. After 5 days of storage, the required force to remove fruits from the vine was measured. The fruit removal force of control and of CO_2 treated fruit decreased. However, treatment with 1-MCP prevented this decrease.

INTRODUCTION

Elevated CO_2 is known to counteract ethylene effects (Sisler and Wood 1988). It has been suggested that CO_2 acts competitively with ethylene at the ethylene receptor binding-site (Burg and Burg 1967, Gorny and Kader 1996). However, this type of inhibition is under debate. Using 1-MCP, it was shown that CO_2 inhibited ethylene production of pear at 2 °C but not through affecting ethylene perception (De Wild et al. 1999). In the present study, it was investigated whether this is also valid for tomato on the vine. These tomatoes are picked as entire bunches (also referred to as cluster tomato or truss tomato). Tomato on the vine was chosen to study another important ethylene effect, namely fruit abscission. Fruit abscission of tomatoes on the vine during the post-harvest period is undesirable. Ethylene can stimulate fruit abscission (Yang 1980). For cherry, Wittenbach and Bukovac (1973) found that CO_2 inhibited abscission at the zone between the pedicel and fruit. In the present study it was investigated whether CO_2 can inhibit this ethylene effect at tomato. A pre-treatment with 1-MCP was used to block the ethylene receptor for an extended time (Sisler and Serek 1997) and subsequently the effect of CO_2 on ethylene production and fruit removal force was studied.

MATERIALS AND METHODS

Plant Material

Experiments were performed with tomato on the vine (*Lycopersicon esculentum* Mill. cv. 'Tradiro') of commercial harvest (red stage).

Treatments

Tomatoes on the vine were treated with 6 ppm 1-MCP during 16 hours at 20 °C. Treatment was done in 20-L dessicators. To prevent the accumulation of CO_2, KOH pellets were placed inside the dessicators. Control tomatoes were left in normal air. Subsequently tomatoes on the vine were placed in dessicators (two clusters per dessicator) which were connected to a flow-through system (day 0). In the flow-through system, pure N_2, O_2 and CO_2 were mixed at a total flow rate of 200 $ml.min^{-1}$ using mass flow controllers. The applied gas partial pressures were 20 kPa O_2 in combination with 0 or 10 kPa CO_2. The relative humidity in the flow-through situation was 83-85%. Two replicates were used per treatment.

Measurement of Ethylene Production

Ethylene production rate was measured at day 3, 4, and 5. The dessicators were closed temporarily. Two gas samples were taken over a time span of 5 hours. Samples were taken by using syringes and subsequently analysed by gas chromatography (gas chromatograph equipped with an alumina column and a FID detector). Tomatoes that were not included in the experiment were used to calculate product density by measuring weight and volume (Baumann and Henze 1983). The free volume of dessicators was calculated by subtracting the estimated product volume (fresh weight divided by density) from the desssicator volume. Considering an increase in water vapour pressure in the closed dessicators, the internal pressure of the dessicators immediately after the first measurement was used to convert ethylene levels from percentages to partial pressures (De Wild et al. 2001). This pressure was determined with a pressure sensor (Druck model PDI 265; Druck, Barendrecht, The Netherlands). The difference in gas partial pressures between the first and the second measurement was converted to moles according to the Ideal Gas Law. Ethylene production rates were calculated by expressing the difference in number of moles between the two measurements per unit time (s) and per unit weight (kg fresh weight at the start of the experiment).

Measurement of Fruit Removal Force

At day 5, the fruit removal force of each fruit from the cluster was determined by tensile technique (Instron type 4200). The peduncle connected to each fruit was clamped between vertical plates. These plates moved upwards with a speed of 10 $mm.min^{-1}$. The force (N) required to separate the fruit from the vine was recorded.

Statistical Analysis

The effects of 1-MCP and CO_2 on fruit removal force were analysed for significant differences by analysis of variance (ANOVA). When significant differences were found, comparisons between pairs of data were made using the least significant differences between means (LSD). The significance level used was 95%.

RESULTS

Ethylene production of control fruit was similar at day 3, 4 and 5 (Table 1). Elevated CO_2 strongly inhibited ethylene production during this period. Inhibition by 1-MCP was less strong. CO_2 inhibited ethylene production also after 1-MCP pre-treatment.

Using the Instron tensile technique, both breaking between fruit and pedicel and between pedicel and peduncle was observed. The fruit removal force was not influenced by the position of the fruit on the vine. The fruit removal force of control fruit had decreased strongly after 5 days of storage (Table 2). With 1-MCP pre-treatment the loss in fruit removal force was completely prevented. CO_2 did not affect the fruit removal force, neither for untreated or 1-MCP treated fruits.

DISCUSSION

Inhibition of ethylene production by CO_2 was much stronger than inhibition by 1-MCP. 1-MCP treatment is expected to have been saturating (Sisler and Serek 1997). Ethylene production was inhibited by CO_2 irrespective of 1-MCP pre-treatment. Elevated CO_2, therefore, must have had an influence on ethylene production other than through ethylene perception. This confirms earlier observations for pear fruit (De Wild et al. 1999).

It was shown in the present experiment that treatment with 1-MCP inhibited loss of fruit removal force. In practice, 1-MCP could be useful to prevent fruits from dropping off the vine in the post-harvest period. This effect of 1-MCP, that is known to block the ethylene receptor binding-site, indicated that the loss of fruit removal force was the consequence of ethylene action. CO_2 did not seem to influence this ethylene action as there was no difference between control and CO_2 treated fruit.

Literature Cited

Baumann, H. and Henze, J. 1983. Intercellular space volume of fruit. Acta Hortic. 138: 107-111.

Burg, S.P. and Burg, E.A. 1967. Molecular requirements for the biological activity of ethylene. Plant Physiol. 42: 144-152.

De Wild, H.P.J., Woltering, E.J. and Peppelenbos, H.W. 1999. Carbon dioxide and 1-MCP inhibit ethylene production and respiration of pear fruit by different mechanisms. J. Exp. Bot. 335: 837-844.

De Wild, H.P.J. and Peppelenbos, H.W. 2001. Improving the measurement of gas exchange in closed systems. Postharvest Biol. Technol. 22: 111-119.

Gorny, J.R. and Kader, A.A. 1996. Controlled-atmosphere suppression of ACC synthase and ACC oxidase in 'Golden Delicious' apples during long-term cold storage. J. Am. Soc. Hortic. Sci. 121: 751-755.

Sisler, E.C. and Wood, C. 1988. Interaction of ethylene and CO_2. Physiol. Plant. 73: 440-444.

Sisler, E.C. and Serek, M. 1997. Inhibitors of ethylene responses in plants at the receptor level: recent developments. Physiol. Plant. 100: 577-582.

Wittenbach, V.A. and Bukovac, M.J. 1973. Cherry fruit abscission: Effect of growth substances, metabolic inhibitors and environmental factors. J. Amer. Soc. Hort. Sci. 98: 348-351.

Yang, S.F. 1980. Regulation of ethylene biosynthesis. HortScience 15: 238-243.

Tables

Table 1. Ethylene production ($pmol.kg^{-1}.s^{-1}$) (means ± standard deviation) of tomato on the vine during storage.

	Day 3	Day 4	Day 5
Control	18.2 ± 1.2	16.9 ± 1.7	16.3 ± 2.5
CO_2	0.8 ± 0.4	1.0 ± 0.5	1.5 ± 0.5
1-MCP pre-treatment	7.3 ± 2.3	8.4 ± 3.1	9.6 ± 3.1
1-MCP pre-treatment and CO_2	1.5 ± 0.2	1.7 ± 0.1	1.4 ± 0.1

Table 2. Mean fruit removal force (N) of tomato on the vine after 5 days of storage. Means followed by different letters are significantly different at $P<0.05$.

	Fruit removal force
Initial (day 0)	21.2 a
Control	15.4 bc
CO_2	12.8 c
1-MCP pre-treatment	21.6 a
1-MCP pre-treatment + CO_2	18.6 ab