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The effect of methyl jasmonate on ethylene production and CO_2 evolution in Jonagold apples

ARTUR MISZCZAK, EDWARD LANGE, MARIAN SANIEWSKI, JANUSZ CZAPSKI*

Research Institute of Pomology and Floriculture, Pomologiczna 18, 96-100 Skierniewice, Poland and *Research Institute of Vegetable Crops, Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland

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Abstract

Apples cv. Jonagold were harvested at the beginning of October and stored at 0°C until treatment between the beginning of December and the end of January. Methyl jasmonate (JA-Me) at the concentration of 1.0, 0.5, 0.1, 0.05, and 0.01 % in lanolin paste were applied to the surface of intact apples. During five days from treatment, samples of cortex with skin (area about 2.0 cm^2) were cut off at a depth of about 2 mm and used for determination of ethylene production, ACC oxidase activity and respiration determined as CO_2 evolution. The production of endogenous ethylene was highest at mid-January (100, 280, and 250 nl/g*h at December, mid-January, and the end of January, respectively). During December and at the beginning of January, JA-Me initially (1-2 days after treatment) stimulated ethylene production and then the production was inhibited. The lower concentration of JA-Me caused initially the greater stimulation and then lower inhibition of ethylene production. However, at the time of maximum production of endogenous ethylene (mid-January) and later, stimulatory effect of JA-Me disappeared. The effect of various concentrations and time of application of JA-Me on ACC oxidase activity had similar trend as endogenous ethylene production. Methyl jasmonate stimulated respiration and this effect was dependent on JA-Me concentration and independent on time of application. The metabolic significance of these findings is discussed.

Key words: apples, methyl jasmonate, ethylene, ACC oxidase, respiration

INTRODUCTION

Methyl jasmonate (JA-Me) and jasmonic acid (JA) were identified in young apple fruits (M e y e r et al., 1984). JA-Me stimulated ethylene production, ACC content and ACC oxidase activity in preclimacteric apples cvs. Jonathan, McIntosh, and Idared (S a n i e w s k i et al., 1986, 1987, 1988). It decreased ethylene production in climacteric and postclimacteric apples (S a n i e w s k i et al., 1986, 1987,

1988) but had no effect on ACC oxidase activity in climacteric apples cv. McIntosh, and inhibited this enzyme activity in climacteric apples cv. Jonathan (N o w a c k i et al., 1990). JA-Me applied to the green or partially coloured skin of detached preclimacteric apple fruit of McIntosh, stimulated chlorophyll disappearance and inhibited anthocyanin accumulation (S a n i e w s k i et al., 1988).

C z a p s k i et al. (1988) showed that JA-Me strongly stimulated polyphenol oxidase activity in apples cv. Jonathan. Electrophoretic patterns of polyphenol oxidase indicated that JA-Me stimulated activity of isozymes already existing in the intact apples, and did not induce the formation of the new ones.

JA-Me greatly stimulated ACC oxidase activity in preclimacteric apples cvs. Barnack Beauty and Wagner stored in normal atmosphere, as well as low O_2 and high CO_2 concentration atmospheres (L a n g e et al., 1993). O l i a s et al. (1992) showed that methyl jasmonate vapour applied at a concentration of 8 ppm, decreased over 50 % the content of volatile esters in Golden Delicious apples after 6 days of treatment. Hexyl ester was inhibited by 50-90 % due to JA-Me. They suggest that methyl jasmonate inhibits the volatile ester forming enzyme system in Golden Delicious apples. Only a slight increase in lipoxygenase activity was noticed in methyl jasmonate treated apples cv. Golden Delicious (O l i a s et al., 1992).

Application of JA-Me vapour greatly stimulated ethylene formation in the cortical and peel tissues of Golden Delicious apples (O l i a s et al., 1991). Recently, P e r e z et al. (1993) found that methyl jasmonate vapours (8 ppm) greatly promoted ß-carotene accumulation and chlorophyll degradation in Golden Delicious apple peel. It seems, that methyl jasmonate could be used to improve colouration and ß-carotene content in apples.

The aim of this work was to determine the effect of wide range of JA-Me concentrations on ethylene production, ACC oxidase activity, and respiration of Jonagold apples during storage.

MATERIAL AND METHODS

Jonagold apples were harvested at the beginning of October and stored at 0°C in normal atmosphere until treatment between the beginning of December and the end of January. One day before treatment they were transferred to room temperature (18°C). Five fruits were taken to each analysis. Methyl jasmonate at concentration of 1.0, 0.5, 0.1, 0.05, and 0.01 % in lanolin paste was applied to the surface of individual, intact apple. Lanolin paste without JA-Me was used as a control. After 5 and 10 hours, and 1, 2, 3, and 5 days from the treatment, samples of cortex with a skin (area about 2.0 cm^2) were cut off at a depth of about 2 mm and tightly sealed in 10 ml vials. After 1h or 2.5 h of incubation 1 ml gas samples were withdrawn from the vials and ethylene and CO_2 contents were determined. ACC oxidase activity was determined through ethylene production by slices treated with 1 ml of 1 mM ACC solution applied on the surface of wounded tissue of slices.

Ethylene was determined using gas chromatography method and CO_2 was analysed using infrared ADC gas analyzer.

RESULTS

At the beginning of December and January slices from apples produced about 100 nl/g*h of ethylene and then (mid-January) considerable increase in the production was noted (Fig. 1). ACC oxidase activity was highest in slices taken from apples at the beginning of December and lower in the ones excised from apples at the end of January (Fig. 1). Respiration, determined as carbon dioxide production, did not change significantly during the period examined (Fig. 1).

At the beginning of December and in January, fruits were treated with various concentrations of methyl jasmonate. Ethylene production, ACC oxidase activity and respiration were determined during the period of five days after treatment. Initially JA-Me stimulated ethylene production and ACC oxidase activity in apple slices. Maximum stimulation was observed on the first day after treatment and then the level of ethylene and ACC oxidase activity declined reaching lowest values 5 days after treatment (Fig. 2 A and B). JA-Me stimulated ethylene production inversely proportional to the concentration (Fig. 2 A). Curves of ethylene production (Fig. 2 A) and ACC oxidase activity (Fig. 2 B) are very similar. It reflects probably mutual dependence. During five days of monitoring JA-Me stimulated the respiration (Fig. 2 C).

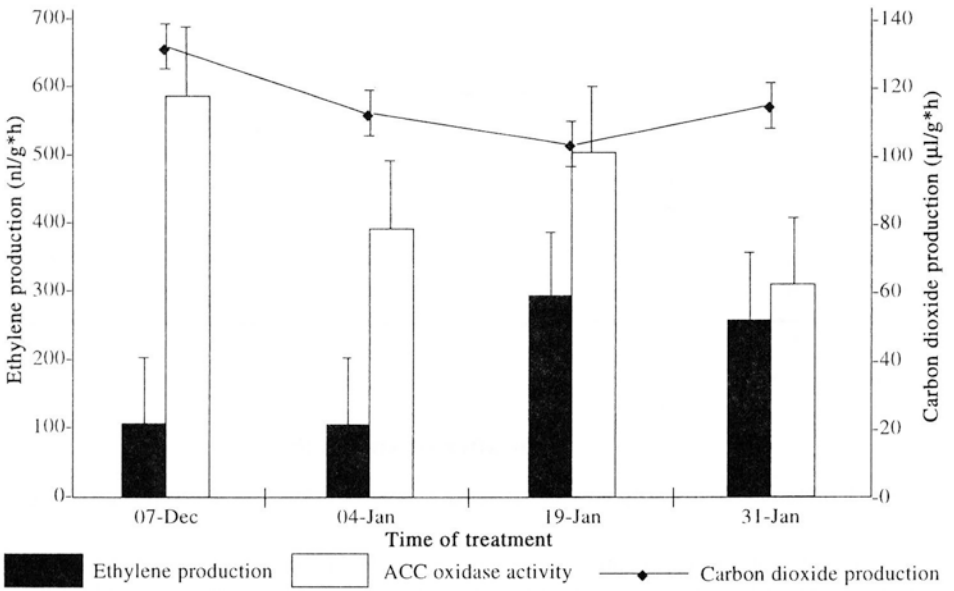

Fig. 1. Changes in ethylene, ACC oxidase activity and carbon dioxide production with the time of storage of Jonagold apples. Vertical bars represent $LSD_{(\alpha = 0.05)}$

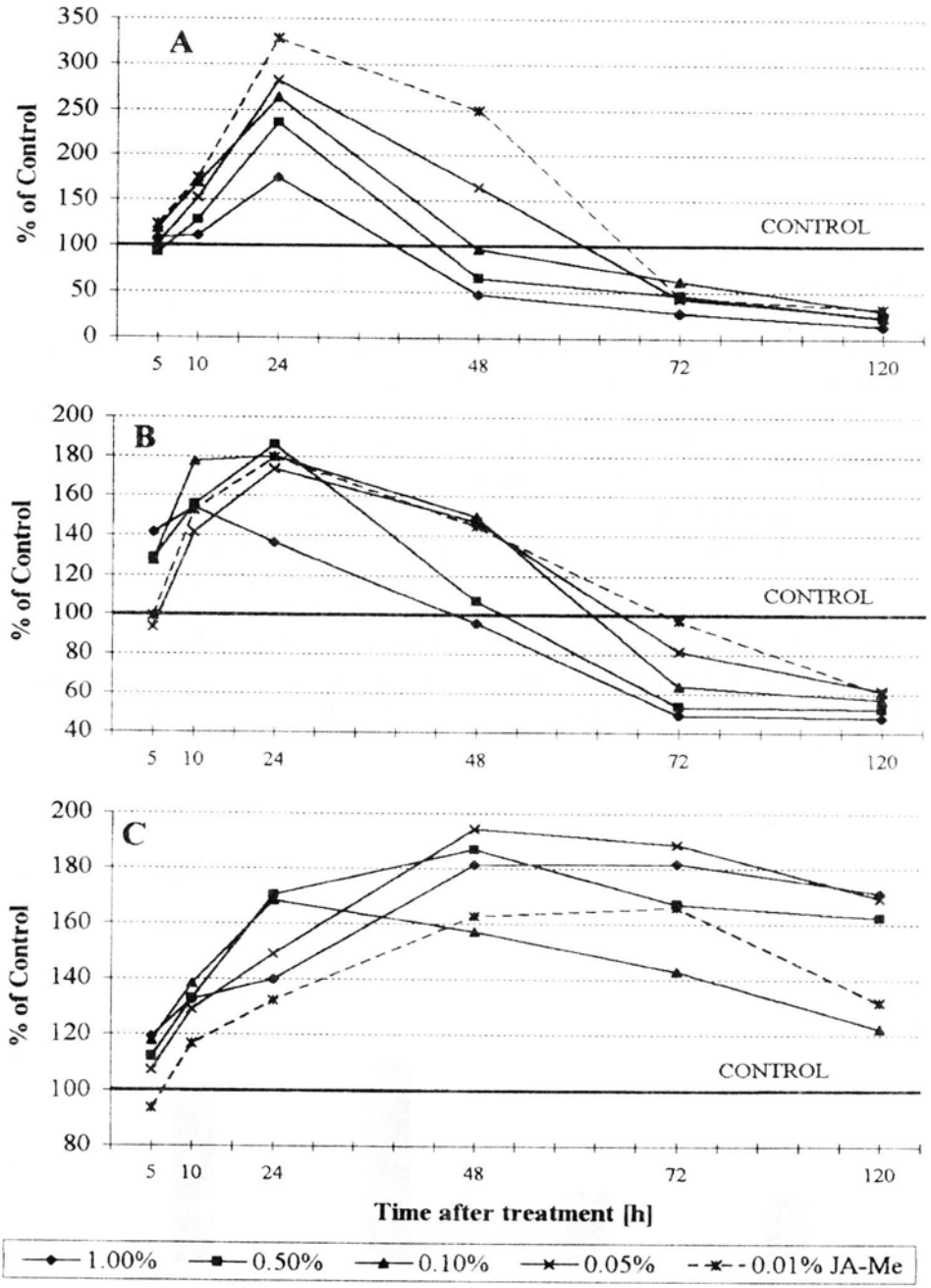

Fig. 2. The effect of various concentrations of methyl jasmonate applied at the beginning of December on ethylene production (A), ACC oxidase activity (B), and carbon dioxide production (C) in Jonagold apples determined during five days after treatment
Data are presented as a percent of the control treated with lanolin only

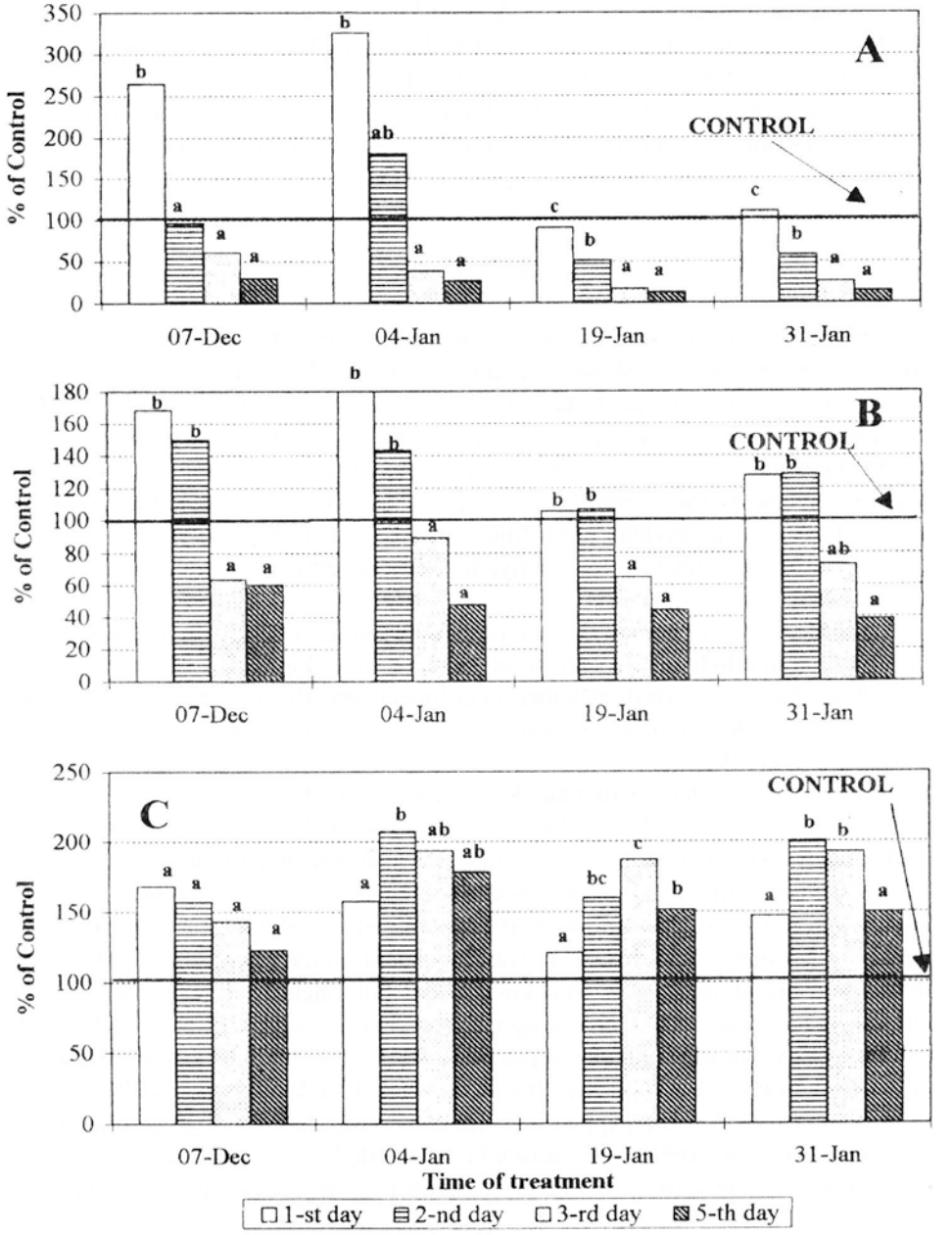

Fig. 3. The effect of 0.1 % methyl jasmonate applied from the beginning of December to the end of January on ethylene production (A), ACC oxidase activity (B), and carbon dioxide production (C) in Jonagold apples determined at the 1st, 2nd, 3rd, and 5th day after treatment
Data are presented as a percent of the control treated with lanolin only
Means followed by the same letter do not differ at the 5 % level of significance (separately for each time of treatment)

As it can be seen from Fig. 3 A (mid-January) stimulatory effect of 0.1 % JA-Me on ethylene production disappeared during apples storage. Similar trend of ACC oxidase activity can be observed (Fig. 3 B).

During the period from the beginning of December to the end of January JA-Me constantly stimulated carbon dioxide production (respiration) in apple slices (Fig. 3 C).

DISCUSSION

Methyl jasmonate stimulated ethylene production, ACC oxidase activity and ACC content in Jonathan, McIntosh and Idared apples (Saniewski et al., 1986, 1988). On the other hand in climacteric and postclimacteric apples JA-Me inhibited biosynthesis of ethylene (Czapski et al., 1988; Saniewski et al., 1986, 1987, 1988). Presented data confirm these effects. As long as the production of endogenous ethylene by slices from Jonagold apples has been relatively low, stimulatory effect of JA-Me on ethylene production and ACC oxidase activity was observed. JA-Me inhibits the biosynthesis of ethylene when the ethylene production increased (Fig. 1, 2, 3).

JA-Me increases carbon dioxide production, independently on the stimulation or inhibition of ethylene biosynthesis at the same time (Fig. 2, 3).

It was found previously that methyl jasmonate greatly increased the respiration of barley leaves during the promotion of senescence (Satler and Thimann, 1981; Popova et al., 1988). Recently, Saniewski and Węgrzynowicz-Lesiak (1995) showed that spraying of intact *Kalanchoe blossfeldiana* with methyl jasmonate induced the abscission of leaves during 2-3 days and evidently increased CO_2 evolution. However, Ueda et al. (1994) found that jasmonic acid did not affect the rate of oxygen consumption by oat coleoptile segments in the presence or absence of IAA, whereas IAA slightly enhanced the rate. We observed that tissue under JA-Me treatment got brown and this effect was dependent on the concentration of JA-Me used (data not shown). It is well known that polyphenol oxidase (PPO) is the enzyme responsible for the browning reaction (Hopfinger et al., 1984) and products of oxidation of phenolic substrates are known as inhibitors of some enzyme activity (Deverall et al., 1961). It was shown that JA-Me stimulates PPO activity in postclimacteric Jonathan apples and simultaneously inhibits ethylene production (Czapski et al., 1988).The relation between ethylene biosynthesis, respiration, polyphenol oxidase activity and methyl jasmonate is now under investigation.

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Wpływ estru metylowego kwasu jasmonowego na produkcję etylenu i wydzielanie CO_2 w jabłkach odm. Jonagold

Streszczenie

Wykazano poprzednio, że ester metylowy kwasu jasmonowego (JA-Me) stymuluje produkcję etylenu, aktywność oksydazy ACC i zawartość ACC w przedklimakterycznych jabłkach odm. Jonathan, McIntosh i Idared. Z drugiej strony w jabłkach w klimakterycznym i poklimakterycznym stadium dojrzałości JA-Me hamuje biosyntezę etylenu. Celem tej pracy było zbadanie wpływu szerokiego zakresu stężeń JA-Me (od 1 % do 0.01 %) na produkcję etylenu, aktywność oksydazy ACC i oddychanie klimakterycznych i poklimakterycznych jabłek odm. Jonagold.

Wykazano, że gdy endogenna produkcja etylenu przez wycinki miąższu owoców była relatywnie niska (owoce we wczesnym stadium klimakterycznym), JA-Me początkowo, po 1-2 dniach traktowania, stymulował, a po dłuższym okresie traktowania hamował zarówno produkcję etylenu jak i aktywność oksydazy ACC. Niższe stężenia JA-Me powodowały początkowo większą stymulację produkcji etylenu, a następnie mniejsze jej hamowanie. Gdy endogenna produkcja etylenu przez wycinki miąższu owoców wzrosła (owoce w stadium tzw. szczytu klimakterycznego i poklimakteryczne), stymulacyjny wpływ JA-Me na biosyntezę etylenu zaniknął. Niezależnie od badanego stadium dojrzałości owocu, JA-Me stymulował oddychanie określane jako tempo produkcji dwutlenku węgla. Związki między biosyntezą etylenu, oddychaniem i zaobserwowanym ciemnieniem miąższu pod wpływem JA-Me będą przedmiotem dalszych badań.