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Methyl Jasmonate Induces Gums and Stimulates Anthocyanin Accumulation in Peach Shoots

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Abstract. The effect of methyl jasmonate (JA-Me) on the induction of gum was studied in relation to the action of ethylene in peach (*Prunus persica* Batsch cv. Benishimizu) shoots. JA-Me applied at concentrations of 0.1–2.5% (w/w) in lanolin paste to current growing or older shoots substantially induced gums 3 days after treatment. The amount of gums exuded increased depending on the dose of JA-Me. Ethephon (2-chloroethylphosphonic acid) at 1 or 2% (w/w) in lanolin induced gum and strongly enhanced the promoting effect of JA-Me on gum formation. JA-Me also induced anthocyanin accumulation in current growing shoots, but ethephon did not. Anthocyanin accumulation in response to JA-Me at a concentration of 10 mg/liter or higher was observed also in the cut shoots of peach. Ethephon (100 mg/liter) substantially inhibited anthocyanin accumulation induced by JA-Me. These facts suggest that JA-Me plays an important role in gum formation as well as ethylene and in anthocyanin accumulation and that these processes are not necessarily accompanied by each other in peach shoots.

Key Words. Anthocyanin—Ethephon—Ethylene—Gum formation—Jasmonic acid—Methyl jasmonate—Peach shoot

Gummosis is the process of the accumulation and exudation of gum from plants. It is a common response to wounding and/or injury by insects and pathogens and some stresses in many plants, especially in species of stone fruit trees of the Rosaceae such as peach, cherry, apricot, and plum (Boothby 1983, Butler 1911, Esau 1965, Olien and Bukovac 1982). Because these stresses have been well known to produce ethylene (Abeles 1973, Barkai-Golan et al. 1989, Imaseki 1985, Yang and Hoffman 1984) and the application of the ethylene-generating compound ethephon induces gum, gummosis has been considered to be mediated by ethylene (Buchanan and Biggs 1969, Bukovac 1979, Hillis 1975, Nair et al. 1980, Olien and Bukovac 1978, 1982, Wilde and Edgerton 1975).

Gum formation in peach shoots and fruits has been reported to be caused by the infection of *Botryosphaeria dothidea* or *Botryodiplodia theobromae* (syn. = *Lasiodiplodia theobromae*) (Chen 1985, Ko and Sun 1992, Li et al. 1995, Wright and Smith 1954) in which jasmonic acid (JA) has been first isolated as a plant growth inhibitor (Aldridge et al. 1971). The occurrence of different JA-related compounds in the fungus *B. theobromae* was documented recently (Miersch et al. 1987, 1991). Methyl jasmonate (JA-Me) has also been found to induce gum in tulip bulbs and stems (Saniewski 1989, Saniewski and Puchalski 1988, Saniewski et al. 1997). Recent studies demonstrated an important role of JA and its related compounds in the signal transduction pathway in response to stresses such as wounding, insect attack, or pathogen infection (Blechert et al. 1995, Howe et al. 1996, Mueller 1997, Reinbothe et al. 1994, Sembdner and Parthier 1993, Seo et al. 1997). These facts suggest that gummosis in trees in response to these stresses is regulated by JA and its related compounds in a way similar to the mode of action of ethylene.

In this paper we report the stimulatory effect of JA-Me on gum formation and anthocyanin accumulation in peach shoots.

Abbreviations: JA, jasmonic acid; JA-Me, methyl jasmonate.

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Table 1. Effects of JA-Me and ethephon on gum formation in intact peach shoots. JA-Me or ethephon was applied alone or simultaneously as lanolin paste to intact peach shoots. Gum formation was observed optically and quantified as relative amounts: −, no gums; + to ++++, increasing degrees (amounts) of gum production (+, trace; ++++, high production).

	Days after treatment		
Treatment	2	3	4
None	−	−	−
JA-Me			
0.1%	−	+	+
0.5%	−	+	++
1.0%	−	++	+++
2.5%	+	++	+++
Ethephon			
1%	+	++	+++
2%	+	++	+++
JA-Me 2.5% + ethephon 1%	++	+++	++++

Materials and Methods

Plant Materials

Mature peach (*Prunus persica* Batsch cv. Benishimizu) trees growing at the Orchard of College of Agriculture, Osaka Prefecture University, Japan were used.

Gum Formation and Anthocyanin Acumulation

JA-Me (0.1, 0.5, 1.0, and 2.5%, w/w) or ethephon (2-chloroethylphosphonic acid, 1.0 and 2.0%, w/w) in lanolin paste as a ring (c about 3 mm in width) was applied to selected branches gently abraded with a polishing cloth. In some experiments, JA-Me in the presence or absence of ethephon (100 mg/liter) was applied as a solution to the cut shoots from currently growing plants or peach shoots that had stopped growing.

After appropriate incubation, gum production and anthocyanin accumulation were observed. In the experiments using the cut shoots of peach, the content of anthocyanin was determined spectrophotometrically by absorption at 530 nm, after extraction of anthocyanin from shoot segments (2 cm in length) excised from the middle part of the cut shoots with 1% HCl in methanol.

Results and Discussion

The application of ethephon at concentrations of 1 and 2% (w/w) in lanolin to gently abraded current growing shoots stimulated gum formation around the site of the application in intact shoots (Table 1). Gentle abrasion had no effect on gum formation, indicating that this abrasion had no serious role in gum formation as a wound signal. The onset of gum formation induced by ethephon took place 2 days after the treatment. This fact indicates that gummosis is regulated by ethylene in peach shoots as is well known.

On the other hand, JA-Me at concentrations of 0.1, 0.5, 1, and 2.5% in lanolin also induced gum formation,

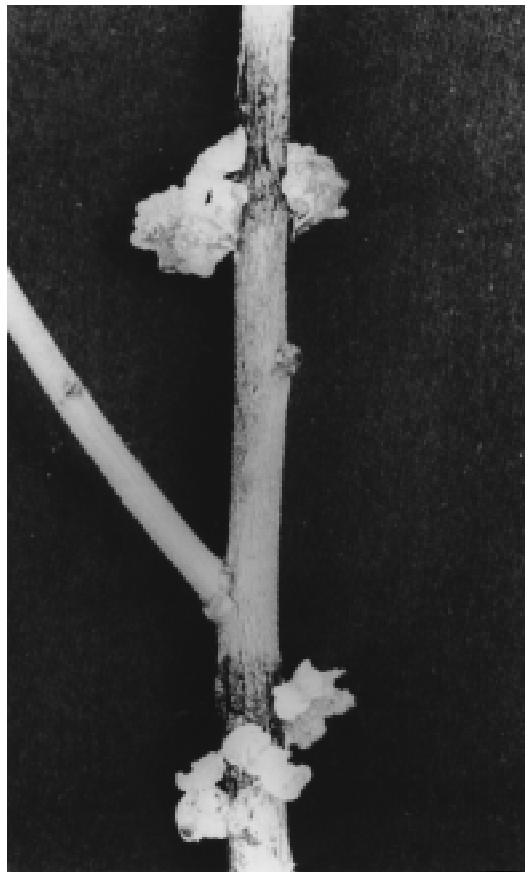

Fig. 1. Gum formation induced by JA-Me (2.5%, w/w) at 3 days after application.

with the onset of gum formation taking place 3 days and 2 days after the treatment, respectively (Table 1 and Fig. 1). The amounts of gum exuded increased as the incubation time was increased and the concentration of JA-Me was higher. The onset of gum formation was also hastened depending on the concentration of JA-Me. Simultaneous application of JA-Me with ethephon strongly enhanced the exudation of gum and shortened the onset of formation as compared with the treatment of JA-Me or ethephon alone (Table 1). The effectiveness of JA-Me or ethephon on gum formation in peach shoot was not different between currently growing shoots and old ones (data not shown). These results suggest that JA-Me regulates gummosis associated with ethylene in peach shoots in response to insect or pathogen attack and other stresses.

Recently, JA and its related compounds have been reported to be produced in response to stresses such as wounding and pathogen infection (Creelman and Mullet 1997, Mueller 1997, Reinbothe et al. 1994, Sembdner and Parthier 1993, Seo et al. 1997). Czapski and Saniewski (1992) suggested that stimulation of ethylene production by wounding and pathogen infection of different

Table 2. Effects of JA-Me and ethephon on anthocyanin accumulation in intact peach shoots. JA-Me or ethephon was applied alone or simultaneously as lanolin paste to the intact peach shoots. Accumulated anthocyanin was observed optically and quantified as relative amounts: −, no anthocyanin accumulation; + to ++++, increasing degrees (amounts) of anthocyanin accumulation (+, trace; ++++, high accumulation).

	Days after treatment		
Treatment	2	3	4
None	−	−	−
JA-Me			
0.1%	−	+	+
0.5%	+	++	++
1.0%	+	+++	+++
2.5%	+	+++	+++
Ethephon			
1%	−	−	−
2%	−	−	−
JA-Me 2.5% + ethephon 1%	+	++	++

organs of tomato plants may be caused by an increased content of endogenous JA or JA-Me which controls biosynthesis of ethylene in tomato. In tulip bulbs, JA-Me has been reported to induce gummosis as well as ethylene production (Saniewski 1989, Saniewski and Puchalski 1988, Saniewski et al. 1997, 1998). These facts strongly support our suggestion that gummosis in response to these stresses is regulated by JA-Me, and possibly by other JA-related compounds, in cooperation with ethylene. Further studies of the changes in the endogenous levels of JA and its related compounds during induction of gums in response to these stresses in peach shoots are required.

Our recent results (unpublished) indicate that JA-Me induces also gum formation in other stone fruit trees, sour cherry (*Prunus cerasus* L.) and apricot (*Prunus armeniaca* L.). Studies on the mode of action of gummosis in other species of Rosaceae are also under the investigation.

In peach shoots, mostly in the apex, in addition to gum induction anthocyanin accumulation is stimulated by the infestation of insects (our observation). Unlike gummosis, applied ethephon had no effect on anthocyanin accumulation in currently growing shoots (Table 2). On the other hand, JA-Me at concentrations of 0.1, 0.5, 1, and 2.5% in lanolin greatly stimulated anthocyanin accumulation when it was applied in lanolin paste to intact peach shoots, the anthocyanin accumulation being observed around the site of the application 2 days after the treatment. Ethephon applied simultaneously with JA-Me showed inhibition of JA-Me-induced anthocyanin accumulation in intact shoots.

The stimulatory effect of JA-Me on anthocyanin accumulation was observed also in the cut shoots of peach. JA-Me applied as a solution stimulated anthocyanin accumulation. Ethephon substantially suppressed JA-Me-induced anthocyanin accumulation as well as in intact shoots (Fig. 2). These facts suggest that the accumulation of anthocyanin in response to wounding in peach shoots is regulated by JA-Me, and possibly with other JA-related compounds, but not by ethylene.

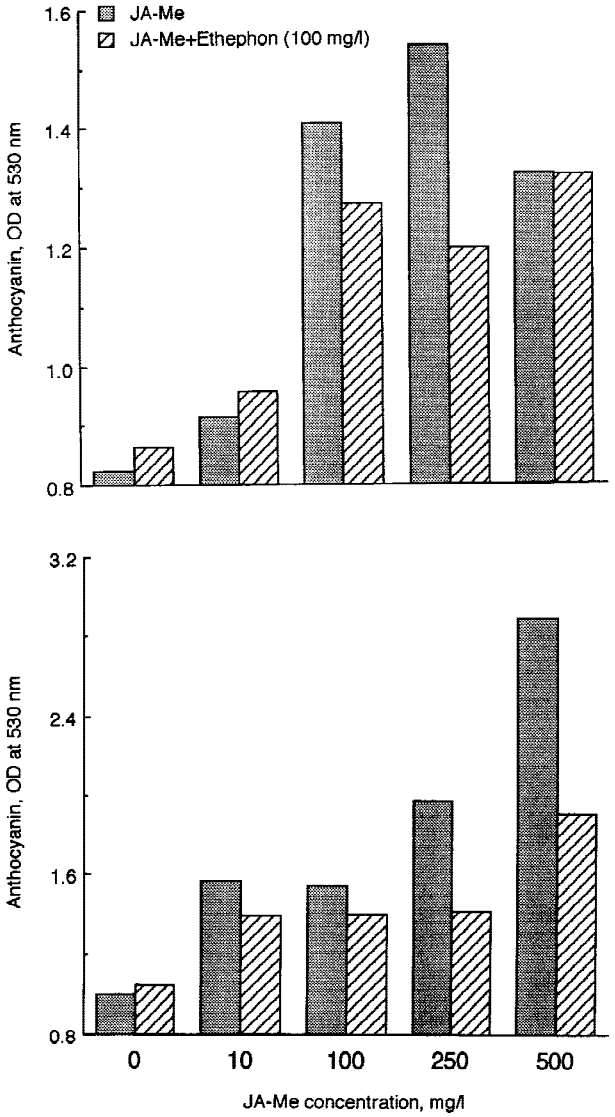

Fig. 2. Effect of JA-Me on anthocyanin accumulation in the cut shoots of peach in the presence or absence of ethephon. Cut shoots of peach (*upper*, cut shoots from current growing shoots; *lower*, cut shoots from stopped-growing shoots) were incubated with various concentrations of JA-Me solution in the presence or absence of ethephon (100 mg/liter) for 3 days. After the incubation, 2-cm segments were excised from the middle part of the shoots and used for anthocyanin extraction (four segments/5 ml of 1% HCl-MeOH).

The stimulatory effect of JA-Me on anthocyanin accumulation has already been found in a wild type of *Arabidopsis* (Feys et al. 1994), soybean hypocotyls (Franceschi and Grimes 1991), and tulips (Saniewski et al. 1998). In tulips and soybean, accumulation of anthocyanin induced by JA-Me was not accompanied by an

increase in ethylene production. These results support that the anthocyanin accumulation in peach shoots is regulated by JA-Me, although it is possible that ethylene negatively regulates JA-Me-induced anthocyanin accumulation.

In conclusion, the stimulation of gum formation is irrespective of anthocyanin accumulation in peach shoots, suggesting that the former is possibly regulated by the cooperation of ethylene, and JA-Me, but the latter is regulated only by JA-Me. The modes of action of JA-Me and ethylene on the induction of gums in peach shoots are now under the investigation.

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