Methyl Jasmonate Induces Gummosis in Plants

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Abstract

Gum in plants is induced by environmental stress factors such as pathogens infection, insect attack, mechanical and chemical injuries, water stress and others. All these factors are considered to act via ethylene produced in plant tissues. Recently we have also shown that jasmonates, a new group of plant hormones, induced gummosis in tulip, peach, apricot, plum and cherry. This review paper describes physiological roles of jasmonates in gum induction and/or production in these plants and chemical compositions of gums. A possible mode of action of jasmonates in the process of gummosis will also be discussed in point of the interaction with ethylene.

Gummosis is the process of accumulation and exudation of gum in plants (Olien and Bukovac 1982a). Phenomena of gummosis are widely spread in the plant kingdom, being resulted from an interaction between plants and environmental factors such as insect damage, infection of fungal and bacterial pathogens, mechanical and chemical injuries, flooding stress and others. All of these environmental factors that stimulate gum exudation have been shown to promote ethylene production in plant tissues as well. Ethylene or ethylene-releasing compounds (*i.e.* ethephon; 2- chloroethylphosphonic acid) also stimulate gum formation in stone-fruit trees and their fruits of the Rosaceae, *e.g.* apricot (*Prunus armeniaca* L., *Prunus mume*) (Bradley *et al.*, 1969, Rosik *et al.* 1971, Li *et al.*, 1995), cherry (*Prunus cerasus* L.) (Olien and Bukovac,1982a, b), peach (*Prunus persica* Batsch.) (Buchanan and Biggs, 1969, Li *et al.*, 1995), plum (*Prunus domestica* L.) (Bukovac *et al.*, 1969), and almond (*Prunus amygdalus* Batsch.) (Ryugo and Labavitch, 1978). Besides them, ethylene also induced gums in tulip (*Tulipa* sp.) bulbs and other bulbous ornamental plants (Kamerbeek and De Munk, 1976), honey mesquite (*Prosopis glandulosa* Forr. var. Glandulosa) (Greenwood and Morey, 1979), *Acacia* sp.

(Baldwin *et al.*, 1999), and *Azadirachta indica* (Nair *et al.*, 1980). These results suggest that ethylene is a common factor involved in the induction of gummosis (Boothby, 1983).

On the other hand, it has recently been shown that jasmonates have a promoting effect on the induction and/or production of gums in some kinds of plants described below. Jasmonic acid (JA), methyl jasmonate (JA-Me) and their derivatives (referred to as jasmonates) are widely distributed in the plant kingdom, showing various biological activities in regulating plant growth and development (Ueda and Kato, 1980, Saniewski, 1995, Creelman and Mullet, 1997, Murofushi *et al.*, 1999, Saniewski *et al.*, 1999). JA and JA-Me have also been demonstrated to play an important role in signal transduction pathway in response to stresses such as wounding, pathogens infection or insect attack, resulting in significant physiological phenomena (Koiwa *et al.*, 1997). It is well known that a rapid increase in endogenous levels of jasmonates, mainly JA, occurs in plants or their organs under stress conditions, for example after mechanical wounding, under osmotic stress conditions and after pathogens infection or insect attack (Saniewski, 1997). These facts strongly suggest that jasmonates are important key compounds on induction and/or production of gums in plants together with or without endogenous ethylene. Jasmonates have also been well known to control ethylene production in plant tissues (Saniewski, 1997).

Tulip bulbs infected by *Fusarium oxysporum* f. sp. tulipae have been shown to produce considerable quantities of ethylene, being enough to cause gummosis in diseased and healthy bulbs stored in the same conditions (Fig. 1). The gummosis in tulips has been found in healthy bulbs by exogenously applied ethylene or ethylene releasing compound, ethephon. Interestingly, JA-Me exogenously applied as a lanolin paste also induced gummosis in bulbs (Fig. 2), stems and basal part of leaves of tulips (Saniewski and Puchalski, 1988). It should be mentioned that under natural conditions for normal growth of tulips, gums were not formed in leaves and stems. Although JA-Me greatly stimulated ethylene production and ACC (1-aminocyclo-propane-1-carboxylic acid) oxidase activity in intact tulips (Saniewski, 1989, Saniewski and Wegrzynowicz-Lesiak, 1994, 1995) and the application of ACC caused an evolution of ethylene much higher than that of JA-Me, ACC did not induce gum formation in stem of tulips. It has been shown, however, that the simultaneous application of ACC with JA-Me greatly accelerates gum formation in stems and leaves of tulip in comparison with JA-Me treatment alone (Figs. 3 and 4, and Table 1) (Saniewski *et al.*, 1998c, Saniewski *et al.*, 2000b). The effect of JA-Me on the induction of gum was also studied in relation to the action of ethylene in peach shoots (Saniewski *et al.*, 1998d). 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. Ethephon at a concentration of 1 or 2% (w/w) in lanolin induced gum and strongly enhanced the promoting effect of JA-Me on gum formation in peach shoots. The gum formation induced by JA-Me as well as ethephon was also shown in other species of the stone-fruit trees, as sour cherry (Fig. 5), sweet cherry and plum, including fruits of plum (unpublished results) (Fig. 6).

Table 1 The effect of JA-Me and ACC on gum induction in base of tulip leaves

Days after treatment Treatments	1.5	3	5	7	9
Control	-	-	-	-	-
JA-Me 0.1%	-	-	traces	traces	traces
JA-Me 0.1% + ACC 1 mM	traces	+	++	++	++
JA-Me 0.1% + ACC 5 mM	traces	+	+++	+++	+++
JA-Me 1.0%	-	-	+	++	++
JA-Me 1.0% + ACC 1mM	+	++	+++	++++	++++
JA-Me 1.0% + ACC 5 mM	+	++	++++	+++++	+++++
ACC 1 mM	-	-	-	-	-
ACC 5 mM	-	-	-	-	-

- no infiltration by gums, + to +++++ increasing leaf area of infiltration by gum

These results suggest that the mode of action of ethylene is quite different among plant species. It might be dependent on quality and quantity of endogenous jasmonates.

Gums are complex of different substances but most important constituents are polysaccharides of highly individual structure. Composition of gum polysaccharides shows variation between species and cultivars in plants (Boothby, 1983). Some reports noted that gum formation is accompanied by the disappearance of starch grains and by breakdown of cell walls (Nair *et al.*, 1980, Boothby, 1983, Morrison and Polito, 1985, Morrison *et al.*, 1987a, b). Gums formed in leaves and stems of tulip induced by simultaneous application of JA-Me and ACC contained ca 16% of uronic acid (but not identified yet), and remaining neutral sugars consisted of arabinose (ca 40%) and xylose (ca 60%). These results suggest that tulip gums consist of glucuronoarabinoxylan (GlcN:Ara:Xyl= 1:2:3). Analysis of cationic composition of ash obtained from gums in tulip stems formed by the application of JA-Me showed high content of calcium and potassium, and in smaller amounts of magnesium and sodium (Saniewski *et al.*, 2000b).

As mentioned above, JA-Me was found to induce gummosis in apricot shoots as well as biotic and abiotic factors (Fig. 7) (Saniewski *et al.*, 2000a). In order to know the mode of action of JA-Me on gum induction and/or formation, chemical composition of polysaccharides (after hydrolysis) in gums of apricot shoots induced by JA-Me as compared with those by ethephon and their mixture was extensively studied, resulted in the successful identification of monosaccharides, and the similarity of a composition consisting of xylose, arabinose and galactose at molar ratio of 1 : 10 : 14, respectively. These results suggest that the biosynthesis pathway(s) of polysaccharides in apricot gums is independent of chemicals inducing gums.

According to the fact described above, JA-Me seemed to be essential factor for gum formation in tulip shoots and ACC makes stem tissues of tulips sensitize to JA-Me action. What kinds of carbohydrates (precursors) participate in gum formation induced by JA-Me in leaves, stems and bulbs of tulip and biosynthesis pathway(s) of polysaccharides consisting gums induced by JA-Me are unknown. Histological studies of tulip stem in different stages in gum formation induced by JA-Me suggest that the degradation products of cell walls and protoplasts contribute to the gum exudates (Saniewski and Dyki, 1997, Saniewski *et al.*, 1998a).
Physiological role of gums in plants has not been clear yet. It has been believed that gums have a function in limiting the spread of fungal and bacterial pathogens by isolating the infected tissues (Boothby, 1983). It appears that jasmonates represent an integral part of the signal transduction chain between stress signal(s) and stress response(s), and interact with ethylene in many physiological processes, including gum induction and/or production. The process of gum induction and/or production induced by these compounds may be regulated by a signal network in which individual signals mediated by ethylene and jasmonates "cross-talk" (Saniewski *et al.*, 1999). Further investigations will be required for the analysis of mechanisms of this kind of "cross-talk" on induction and/or production of gums in plants.

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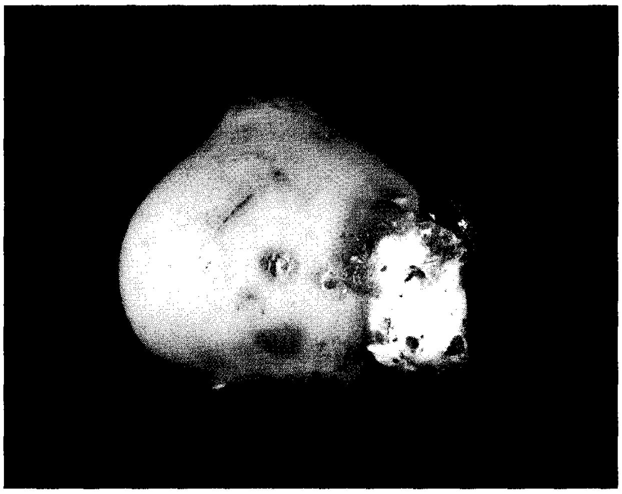


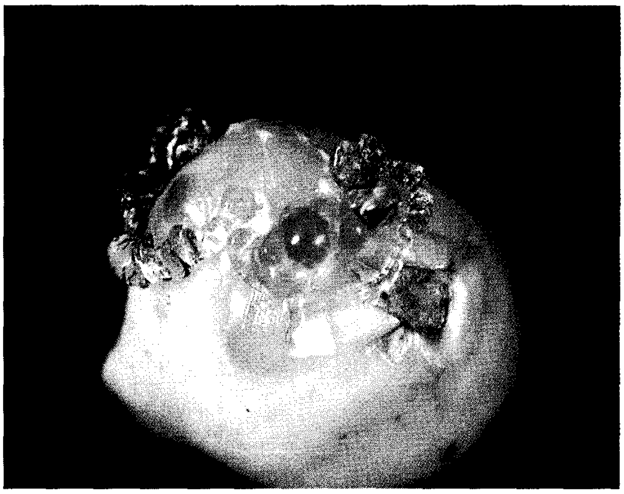
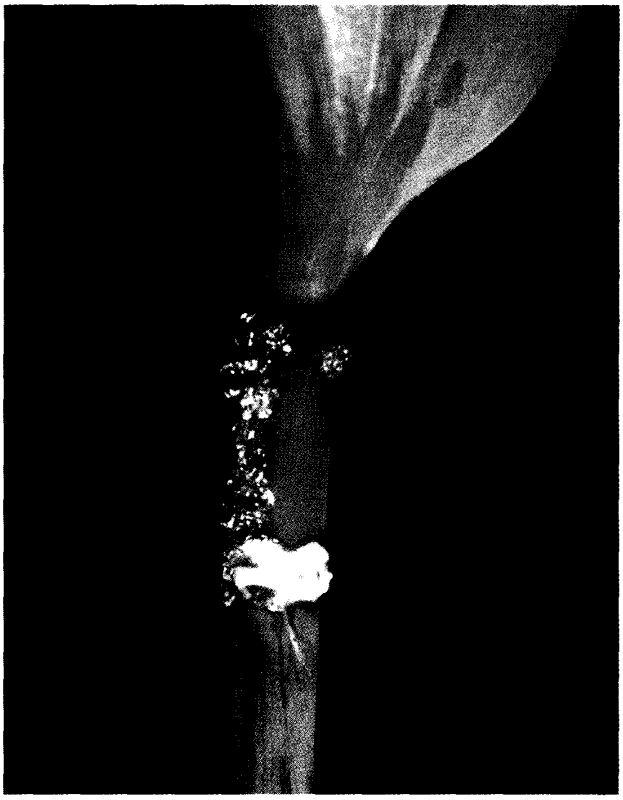


Fig. 1 (left). Gum exudation in tulip bulb cv. Apeldoorn infected by *Fusarium oxysporum* f. sp. tulipae: Gum exudate and mycelium can be observed

Fig. 2 (right). Gum induction by methyl jasmonate in healthy tulip bulb cv. Apeldoorn



Figs. 3 (left) and 4 (right). Gum exuded on the basal part of leaf (left) and the basal internode (right) of tulip treated with methyl jasmonate + ACC

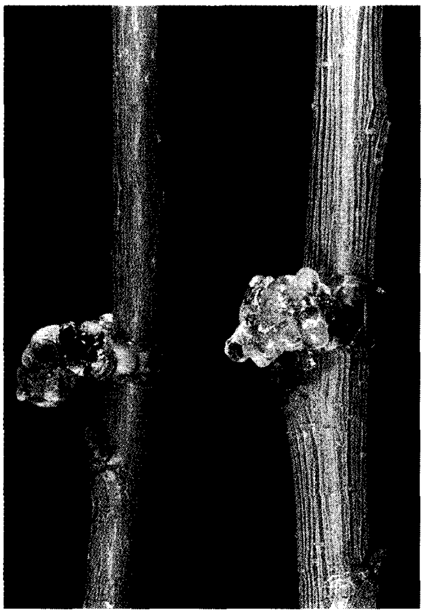


Fig. 5. Gum induction by methyl jasmonate in lanolin paste in sour cherry shoots

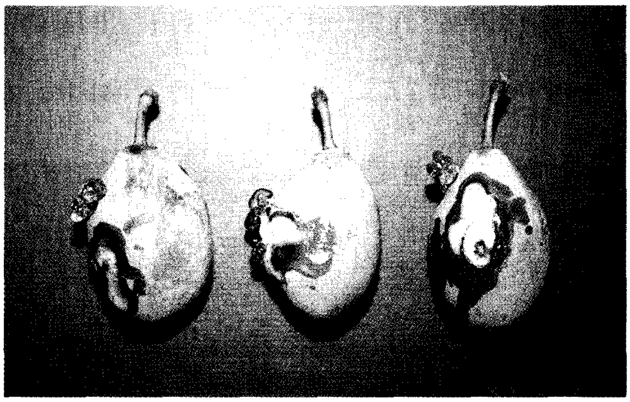


Fig. 6. Gum exudation in plum (*Prunus domestica*) fruits

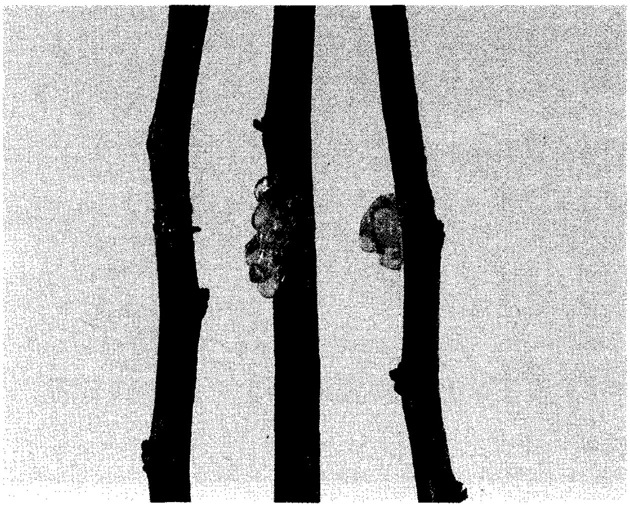


Fig. 7. Gum induction by ethephon and methyl jasmonate, applied in lanolin paste, in apricot shoots; from left - control, ethephon, methyl jasmonate