METHYL JASMONATE-INDUCED GUM PRODUCTION IN TULIP BULBS IS STIMULATED BY GIBBERELLIC ACID

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A B S T R A C T

This manuscript reports that for tulip bulbs (*Tulipa gesneriana* L. ‘Apeldoorn’), simultaneous application of methyl jasmonate (JA-Me) with gibberellic acid (GA) increases gum formation in the bulbs, compared to JA-Me applied alone. After the dry scales of the bulbs were removed, the bulbs were treated with JA-Me and GA starting from the beginning of July 20 until November 30. Treated bulbs were stored in a laboratory room in natural light conditions. Gums produced by each treatment were weighted one month after treatment. JA-Me, at concentrations of 0.5 and 1.0% in lanolin, was applied alone, and also applied simultaneously with GA at concentrations of 0.25, 0.5 and 1.0% in lanolin. All the concentrations of GA applied simultaneously with JA-Me, substantially stimulated gum production in tulip bulbs. The production of gums decreased gradually from the beginning of October. The possible mode of action of GA to stimulate gum production in tulip bulbs is also discussed. The focus is on sugar metabolism and ethylene production.

Key words: tulip, gum, methyl jasmonate, gibberellic acid

INTRODUCTION

Gums in plants are induced by some environmental stress factors such as pathogen infection, insect attack, mechanical and chemical injuries, and water stress. All of the environmental factors are considered to act via ethylene produced in plant tissues (Boothby, 1983). The physiological role of gums in plants is not clearly understood. Gums may play a role in inhibiting the spread of bacterial and fungal pathogens, and inhibiting the spread of insects within infected tissues to healthy ones. Thus, gummosis is strictly connected with the plant's defense system against infection and insect attack.

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 (Kamerbeek and De Munk, 1976). Exogenous ethylene or ethylene-releasing compound (ethephon) also induced gummosis in healthy tulip bulbs, but not in the other tulip organs such as the stem and leaves (De Hertogh et al., 1980). On the other hand, jasmonates have been reported to show a promoting effect on the induction and/or production of gums not only in bulbs but also in the stem, base of the leaves and in the pistil of tulips (Saniewski and Puchalski, 1988) as well as in stone-fruit trees and the fruits of the *Rosaceae* (Saniewski et al., 1998a, 2000b, 2006). Besides ethylene, a rapid increase in endogenous levels of jasmonates, mainly jasmonic acid (JA), has been found in plants under stress conditions, during pathogen infection and insect attack, mechanical wounding, injuries caused by heavy metals, osmotic stress, and others (Saniewski, 1997; Saniewski et al., 1999, 2002). Jasmonates have been known as compounds controlling ethylene production in plant tissues as well (Saniewski, 1997). Simultaneous application of methyl jasmonate with 1-aminocyclopropane-1-carboxylic acid (ACC) or ethephon greatly accelerated gum formation in bulbs, stem and leaves of tulips (Saniewski et al., 1998b, 2000a, 2004). The facts described above strongly suggest that the induction and the production of gums are regulated by a signal network of jasmonates and ethylene, especially by cross-signals between them. In this paper, we report that gibberellic acid (GA) substantially stimulates gum formation in tulip bulbs at different stages of flower bud development. This is the first report to show a promoting effect of GA in the presence of JA-Me, on gum formation in tulip bulbs. A possible GA mode of action is also discussed which focuses on sugar metabolism and ethylene production.

MATERIAL AND METHODS

The experiments were performed with the bulbs of tulip (*Tulipa gesneriana* L. 'Apeldoorn') from commercial stocks. After lifting, the bulbs with circumferences of 10-12 cm were stored at 18-22 ^{o}C in natural light conditions. Starting from July

20 until November 30, after removal of dry scales, the bulbs were treated around the basal scale side (about 1.5 cm width) with methyl jasmonate (JA-Me) at concentrations of 0.1, 0.5 and 1.0% in lanolin, and with a mixture of the concentrations of JA-Me with gibberellic acid (GA) at concentrations of 0.25, 0.5 and 1.0% in lanolin. A lot of 10 bulbs were used in each treatment. Treated bulbs were stored in a laboratory room at 20-23 ^{o}C in natural light conditions. Dry weight of gums produced by each treatment was determined one month after treatment. The experiment was repeated twice. The data were subjected to an analysis of variance and Duncan's multiple range test at 5% of significance was introduced for means separation.

RESULTS AND DISCUSSION

Methyl jasmonate (JA-Me) used at concentrations of higher than 0.5, substantially induced gummosis in tulip bulbs. Gibberellic acid (GA) applied alone did not induce gummosis but GA at all concentrations with JA-Me at concentrations of 0.5 and 1.0% substantially stimulated gum production in tulip bulbs (Figs 1-3). Gum production in tulip bulbs responding to JA-Me decreased gradually from July to November. This result suggests that susceptibility and/or responsiveness of immature tulip bulbs to JA-Me exogenously applied, is much higher than that of mature one. The relationships between JA-Me and tulip bulb age is quite similar in the case of GA (Figs 1-3). The production of gums in tulip bulbs after treatment of GA in the presence of JA-Me, was highest in July and very low in November. This kind of differential reaction of tulip bulbs to formation of gums after treatment with methyl jasmonate, ethylene, or a mixture of these compounds at different period of flower bud formation, has already been described (Saniewski et al., 2004). Interaction of jasmonates and GA has been thoroughly reported in other plant systems. Ranjan and Lewak (1994) showed the additive stimulatory effect of jasmonic acid with GA on the germination of embryos isolated from dormant apple seeds. Traw and Bergelson (2003) also found that gibberellin A_3 and jasmonic acid had a synergistic effect on the production of trichomes on the leaves in *Arabidopsis*. Such a finding suggests that there are important interactions of these compounds in plant morphogenesis but the mechanism of the interaction is still unknown.

The mode of action of GA to stimulate gum production induced by JA-Me in tulip bulbs, has not been clarified yet. A possibility that GA enhances susceptibility and/or responsiveness of tulip bulbs to JA-Me exogenously applied, has not been excluded. One possible explanation for the stimulatory effect of GA on gum production induced by JA-Me, is that GA induces sugar molecules resulted from starch degradation, which will be partially used as substrates of polysaccharides in gum production. GA has been well known to stimulate α-amylase activity in

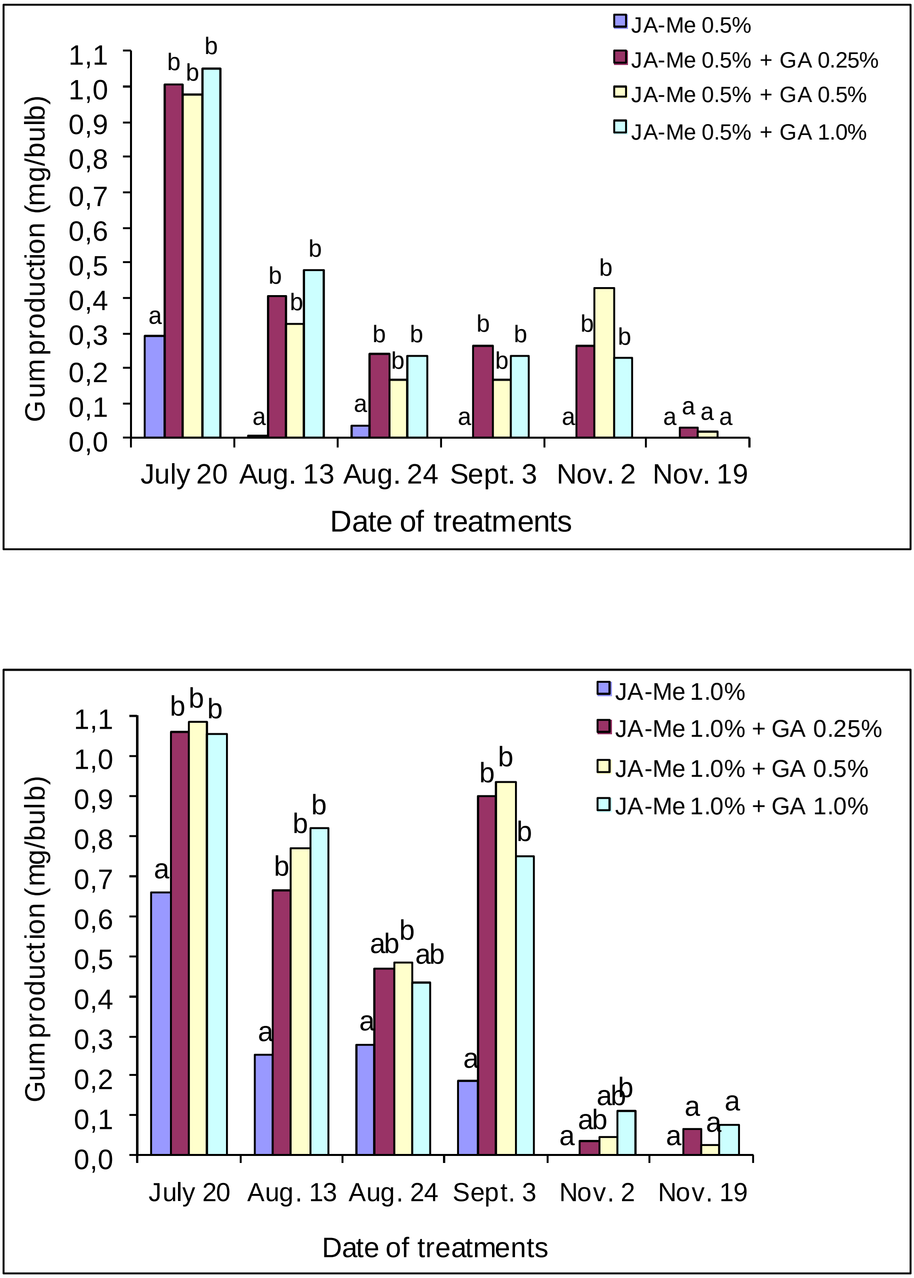

Figure 1. The effect of methyl jasmonate (JA-Me) and its interaction with gibberellic acid (GA) on gum production in tulip bulbs 'Apeldoorn' at different period after lifting

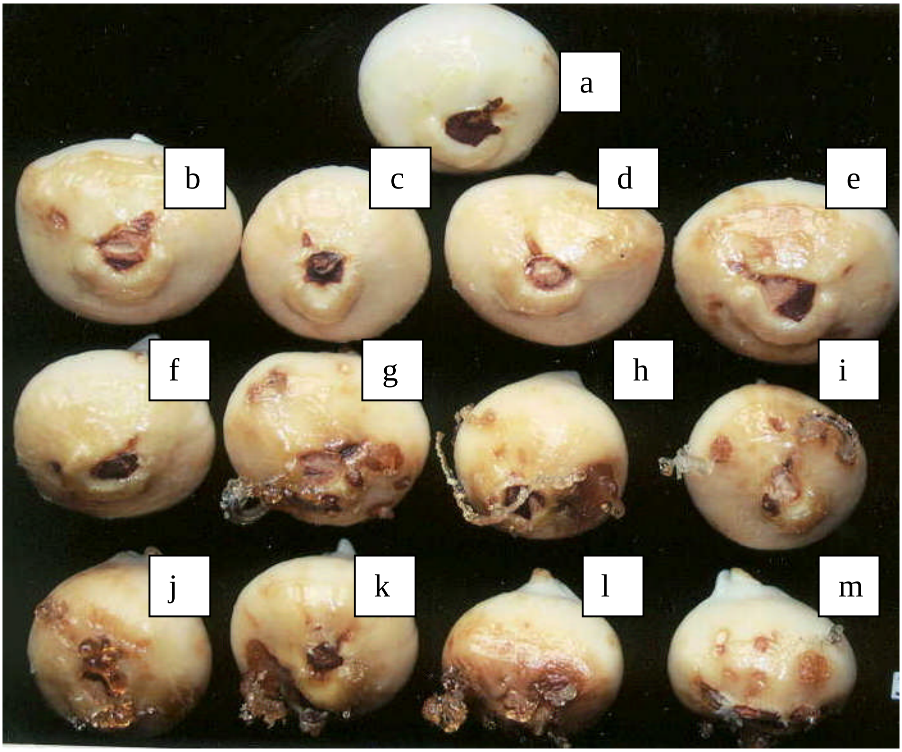

Figure 2. The effect of JA-Me and its interaction with GA on gum production in tulip bulbs 'Apeldoorn'. Treatment was made on August 24 and bulbs were stored in room at natural temperature and light conditions. Photographed on September 20
a) control, lanolin paste only;
b) JA-Me 0.1%; **c)** JA-Me 0.1% + GA 0.25%; **d)** JA-Me 0.1% + GA 0.5%; **e)** JA-Me 0.1% + GA 1.0%;
f) JA-Me 0.5%; **g)** JA-Me 0.5% + GA 0.25%; **h)** JA-Me 0.5% + GA 0.5%; **i)** JA-Me 0.5% + GA 1.0%;
j) JA-Me 1.0%; **k)** JA-Me 1.0% + GA 0.25%; **l)** JA-Me 1.0% + GA 0.5%; **m)** JA-Me 1.0% + GA 1.0%

endosperm of barley (Paleg, 1960; Varner, 1964; Skadsen, 1993). Although in our studies, GA did not increase gum formation induced by ethephon in tulip bulbs (data not presented). Another possibility is that stimulation of ethylene production induced by GA enhances gum production induced by JA-Me. Garcia-Martinez et al. (1984) reported the effect of gibberellins A_1 (GA_1) on the production of ethylene by cowpea (*Vigna sinensis* cv. Blackeye pea no. 5) epicotyls explants and its relationship to epicotyls elongation. Treatment with GA_1 induced the production of ethylene which began 10 h after GA_1 application. In addition, the yield of ethylene was proportional to the amount of GA_1 injected.

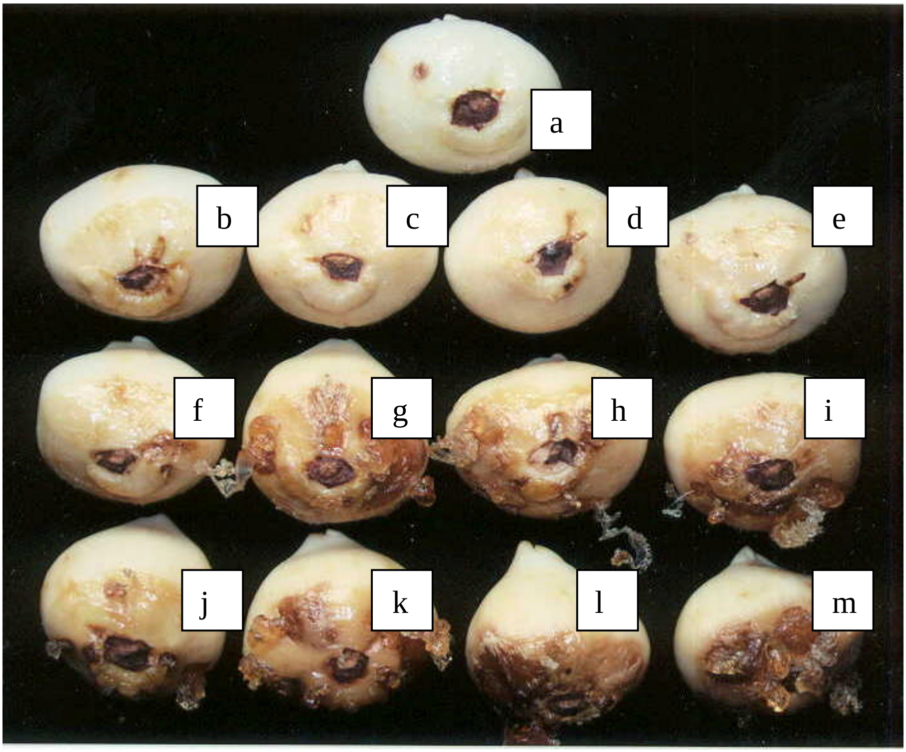

Figure 3. The effect of JA-Me and its interaction with GA on gum production in tulip bulbs 'Apeldoorn'. Treatment was made on September 3 and bulbs were stored in room at natural temperature and light conditions. Photographed on October 5
a) control, lanolin paste only;
b) JA-Me 0.1%; **c)** JA-Me 0.1% + GA 0.25%; **d)** JA-Me 0.1% + GA 0.5%; **e)** JA-Me 0.1% + GA 1.0%;
f) JA-Me 0.5%; **g)** JA-Me 0.5% + GA 0.25%; **h)** JA-Me 0.5% + GA 0.5%; **i)** JA-Me 0.5% + GA 1.0%;
j) JA-Me 1.0%; **k)** JA-Me 1.0% + GA 0.25%; **l)** JA-Me 1.0% + GA 0.5%; **m)** JA-Me 1.0% + GA 1.0%

Simultaneous application of JA-Me with 1-aminocyclopropane-1-carboxylic acid (ACC) or ethephon greatly stimulated gum production in the bulb and stem of tulips (Saniewski et al., 1998b, 2000a, 2004). Further investigations will be required to clarify the mode of action of a promoting effect of GA on gum production induced by JA-Me.

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INDUKCJA GUM W CEBULACH TULIPANA PRZEZ JASMONIAN METYLU JEST STYMULOWANA PRZEZ KWAS GIBERELINOWY

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S T R E S Z C Z E N I E

Infekcja cebul tulipanów przez *Fusarium oxysporum* f. sp. *tulipae* powoduje wytwarzanie dość dużej ilości etylenu, który indukuje tworzenie się gum w cebulach. Jasmonian metylu (JA-Me) podany w paście lanolinowej na cebule tulipanów również indukuje wytwarzanie się gum w cebulach. Etefon, jako źródło etylenu, podany łącznie z jasmonianem metylu silnie stymuluje produkcję gum w cebulach w porównaniu z traktowaniem samym etefonem lub jasmonianem metylu.

Obecne badania wykazały, że łączne traktowanie cebul tulipana jasmonianem metylu z kwasem giberelinowym (GA) zwiększa ilość tworzących się gum w porównaniu z traktowaniem samym jasmonianem metylu. Cebule tulipanów 'Apeldoorn' po usunięciu suchej łuski były traktowane JA-Me łącznie z GA w okresie od początku lipca do listopada włącznie. Cebule były przetrzymywane w laboratorium w naturalnych warunkach świetlnych (15 cebul w kombinacji). Gumy wytwarzane w poszczególnych kombinacjach były ważone po 1 miesiącu od traktowania. Jasmonian metylu w stężeniach 0,1, 0,5 i 1,0% był zastosowany pojedynczo i łącznie z GA w stężeniach 0,1 0,5 i 1,0%. JA-Me tylko w stężeniach 0,5 i 1,0% indukował tworzenie się gum w cebulach tulipana. Wszystkie stężenia GA zastosowane łącznie z JA-Me w stężeniach 0,5 i 1,0% stymulowały indukcję gum w porównaniu z traktowaniem samym JA-Me. W czasie od lipca do listopada ilość wytwarzanych gum stopniowo się zmniejszała. GA podany łącznie z etefonem nie zwiększał produkcji gum w cebulach tulipana w porównaniu z traktowaniem samym etefonem. Mechanizm stymulującego działania kwasu giberelinowego na wytwarzanie gum indukowanych przez jasmonian metylu jest w pracy dyskutowany.

Słowa kluczowe: tulipan, gumy, jasmonian metylu, kwas giberelinowy