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Foliar Application of Salicylic Acid and Methyl Jasmonate on Yield, Yield Components and Chemical Properties of Tomato

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ABSTRACT

This study aimed at studying the role of pre-application with salicylic acid (SA) (0.5 and 1 mM) and methyl jasmonate (MJ) (0.5 and 1 mM) and their combination on yield quantity and quality of tomato fruits. The results showed that the foliar spray of SA (0.5 mM) significantly increased vegetative and reproductive growth, yield and fruit quality, while reduced blossom end rot. On the contrary, MJ (1 mM) application significantly decreased vegetative growth while increasing reproductive growth. The application of 0.5 mM MJ+0.5 mM SA increased total soluble solids (TSS), titratable acidity (TA) and vitamin C content. In conclusion, application of 0.5 mM MJ+0.5 mM SA improved the yield and fruit quality of tomato.

Keywords: Tomato, Salicylic Acid, Methyl Jasmonate, Vegetative growth, Reproductive growth,Yield, Fruit quality.
ABBREVIATIONS: Salicylic acid; SA, Methyl Jasmonate; MJ, Total soluble solids; TSS, Titratable acidity; TA,.

INTRODUCTION

Tomato is one of the most popular and widely grown vegetable crops, ranking second in importance to potato in Iran. It is an important condiment in most diets and a very cheap source of vitamins. Tomato is a good source of vitamins A, C and E, and minerals that are very good for body and protect the body against diseases.. It is, therefore, highly desirable to explore possible ways and means to enhance the productivity of this important crop employing cost-effective and easy to use techniques. Salicylic acid (SA) has been identified as one of the components of the signaling pathway, participating in the regulation of wide range of physiological processes in plants. Salicylic acid can also play a significant role in plant water relations, photosynthesis and growth in plants (Arfan *et al.,* 2007). Abd El-al, (2009) found that the foliar application of salicylic acid plays a great role in improving the productivity of sweet pepper plants. Fariduddin *et al.,* (2003) reported that the dry matter accumulation was significantly increased in *Brassica juncea*, when lower concentrations of salicylic acid were sprayed. Jasmonic acid (JA) and its methyl ester (methyl jasmonate, MeJA), are cyclopentanone compounds and are regarded as naturally occurring plant growth regulators (Sembner and Parthier, 1993). It also has been reported that MeJA mitigated the ROS effects in strawberry under water stress and in maize seedlings subjected to paraquat (Norastehnia *et al.,* 2006). Likewise, MeJA treatment decreased chlorophyll content of *Arabidopsis thaliana* (Jung, 2004). Ghasemnezhad and Javaherdashti (2008) expressed that MeJA could enhance the total phenolics and therefore induce the defense mechanism of raspberry against low temperature stress. The aim of the present study was to test the

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effects of foliar spraying of methyl jasmonate and salicylic acid alone or in combination on the growth, yield, fruit quality characteristics and blossom end rot incidence of tomato fruit.

MATERIALS AND METHODS

Plant Growth Conditions and Treatments

The experiment was conducted in 2012/2013 season under field conditions in Ilam (Elevation 1339 m, Latitude East 33.638, Longitude North 46.431), Iran. The soil of the experimental field was silty loam in texture with a pH of 6.5, total N (2.4%), total C (1.35%), a C/N ratio of 0.45, 77, 114 $mg{\cdot}kg^{-1}$ of P, and K, respectively, and with an EC of 0.078 $ds{\cdot}cm^{-1}$. Seeds of Tivi F1 tomato were sown in January and were transplanted during March. There were 3 ridges in 1 subplot and 10 plants in each ridge. Row-to-row and plant-to-plant distances were 75 cm and 30 cm, respectively. The aim of the experiment was to study the effect of methyl jasmonate (0.5 and 1 mM), salicylic acid (0.5 and 1 mM) and distilled water as control foliar application 30 days after transplanting and when the fruits were berry-sized. A non-ionic as wetting agent was used at 0.1%. A back-held spray pump was used for application of the chemicals. After each treatment, the pump was washed thoroughly. Distilled water containing a comparable amount of the wetting agent was sprayed on the plants in the control treatment. All foliar sprays were carried out early in the morning. Plant height, number of fruits per cluster, total yield, mean fruit weight, soluble solid content, total titrable acid, vitamin C, and leaf total nitrogen and potassium contents were estimated.

Measurements

Plant height was determined for 5 plants in the middle row in each treatment after the first picking. For this purpose, the plant height from the soil line to the top was determined with a measuring tape and averaged to represent corresponding treatments. The number of branches was counted for the middle ridge in each treatment at the first picking and the average number of branches per plant was calculated. Total nitrogen of the sample was determined by Kjeldahl method (Kacar 1972). For determination of K contents of leaf, plant samples were air-dried and were then ground. Leaf K was determined after dry digestion of dry and sub-samples in a HCL preparation. Potassium was determined by flame photometry. Lycopene in fruits was estimated as described by Sadasivam and Manikam (1992). Nitrate reductase activity (NRA) was determined by the method of Silveira et al., (1998). The number of flower clusters per plant, number of fruits per cluster, and number of fruits per plant were determined for 5 plants in the middle row of the plot. The total yield for each treatment was calculated by weighing the fruit picked in each plot and converting the weight to yield per hectare. Sub-samples (10 g) were pressed through cheese cloth to extract the juice. Total soluble solids were determined using a portable refractometer (Sper Scientific Ltd., Scottsdale, Ariz.) standardized with distilled water. Total titrable acid and vitamin C was measured by NaOH (0.1 M) titration and indophenol's method according to Horvitz *et al.,* (1970). Blossom end rot incidence was estimated by counting the total number of fruits and showing the symptoms in each plot. Incidence of the diseases was expressed as a percentage of total fruits. The fruit firmness was recorded with the help of a pressure meter (OSK 10576 CO., Japan). For this purpose, 5 fruits from each treatment were taken and penetration force was measured by gently inserting the probe into the equatorial region of the fruit. The readings for all 5 fruits were averaged to represent the corresponding treatments. During the trial, three plants per experimental unit were sampled and fruit numbers and weight were determined. Chlorophyll was determined using chlorophyll meter (SPAD-502, Minolta Co. Japan), which was presented by SPAD value. Average of 3 measurements from different spots of a single leaf was considered.

Statistical Analysis

The experiment was laid out factorial in RCBD with 4 replications, each consisting of 3 pots with each pot containing one plant. Data were analyzed by SPSS 16 software and comparing averages was done by Duncan's test and a probability value of %5.

RESULTS

Vegetative factors and chemical contents in tomato leaves

As shown in table 1, there is significant ($p<0.05$) differences observed between the different treatments; methyl jasmonate (MJ) and salicylic acid (SA) on vegetative factors and chemical contents per plant. Maximum plant height (141.12 cm), dry weight (4.8 g), leaf chlorophyll content (20.12 SPAD), and total N (2.51%) and K (2.14%) contents were obtained when 0.5 mM SA was used. The results in table (1) indicated an decrease in plant height, dry weight and total N and K contents in fruits at the higher SA and MJ concentration (1 mM) in comparison with the lower concentrations of SA and MJ (0.5 mM).

Table 1. Influence of SA and MJ application on leaf N, K and chlorophyll contents, and vegetative and reproductive growth of tomato plants.

Treatment	Plant height (cm)	Chlorophyll (SPAD)	N (%)	K (%)	D. W. (g/100g F.W.)	Fruits per plant	Number of branches	Yield (t ha^{-1})	Flowers per cluster	Fruit weight (g)	Fruits per cluster
Control	98.6b	16.18ab	1.54c	1.20c	4.00b	60.14c	4.00c	12.11c	13.14c	70.12c	4.11c
0.5 mM MJ	100b	8.23d	2.14b	1.6b	3.11bc	97.14a	6.8ab	20.00a	18.15b	98.14a	6b
1 mM MJ	79.14cd	8.41d	1.84b	1.23bc	1.5c	92ab	5.41bc	18.12b	16.2bc	80.5bc	6.08b
0.5 mM SA	141.12a	20.12a	2.51a	2.14a	4.80a	98.12a	7.00ab	22.15a	17.9b	100a	6.14b
1 mM SA	102.3b	17.14ab	2b	1.81b	3.18bc	82.5b	6.18b	17bc	16bc	84.5bc	6b
0.5 mM MJ+0.5 mM SA	95.00b	15.8c	1.91b	1.2bc	3.00bc	100.31a	8.14a	26.15a	22.14a	106.1a	7a
0.5 mM MJ+1 mM SA	95.17b	15.36c	1.85b	1.79b	3.79b	90.4ab	7.64ab	18b	18b	88.1b	6.54ab
1 mM MJ+0.5 mM SA	84.17c	11.2cd	1.79b	1.2bc	2.9bc	95.4ab	5.39bc	18.4b	16.4bc	94.8ab	5.12bc
1 mM MJ+1 mM SA	85.2c	10.9cd	1.8b	1.31bc	1.89c	91.4ab	4.31c	18.14b	13.2c	94.15ab	5bc

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

Fruits per cluster, number of branches per plant, yield, fruit weight and fruits per plant of tomato

As shown in table 1, Application of MJ or SA or their combination significantly increased reproductive growth parameters.The maximum number of fruits per cluster (7), number of flowers per cluster (22.14), yield (26.15 t ha^{-1}), number of fruits per plant (100.31), fruit weight (106.1), number of branches per plant (8.14) and fruits per plant (100.31) were obtained with 0.5 mM MJ+0.5 mM SA foliar application (Table 1).

Fruit quality and nitrate reductase activity

Application of SA and MJ increased total soluble sugars (TSS), titratible acidity (TA) and vitamin C, fruit firmness, pH, fruit lycopene content of tomato fruits. The maximum TSS (6.41 Brix), TA (4.8%) and vitamin C (15.16), fruit firmness (3.56 kg cm^{-2}), pH (3%), fruit lycopene content (2.13) were obtained when plants were sprayed with 0.5 mM MJ+0.5 mM SA (Table 2). On the contrary, the maximum blossom end rot (22) and nitrate reductase activity (3.21 μ mol NO_2/g fw/hr) were obtained in control (Table 2). The nitrate reductase activity was significantly affected by the foliar application SA or MJ, in comparison to the control, however, there were no significant differences among the SA, MJ concentrations and their combination (Table 2).

Table 2. Effect of SA and MJ on chemichal properties, fruit firmness and blossom end rot of tomato fruits.

Treatment	TSS (°Brix)	Vitamin C (mg. 100 g fresh fruit^{-1})	TA (%)	pH	Blossom end rot (%)	Fruit firmness (kg cm^{-2})	Fruit lycopene content (mg/100 g)	Nitrate reductase activity (μ mol NO_2/g fw/hr)
Control	4.32c	8.14c	2c	1.5cd	22a	2c	1acd	3.21a
0.5 mM MJ	5.83b	11.9b	4.67a	2.8a	11.8b	2.43b	1.86ac	2.91b
1 mM MJ	5.9b	12b	2.98b	2c	11.86b	2.5b	1.23b	3b
0.5 mM SA	6.17b	11.69b	3b	2.67ab	11.92b	2.49b	1.2b	3.01b
1 mM SA	5.89b	11.86b	5a	3.36a	7.3c	2.56b	1.8ac	3b
0.5 mM MJ+0.5 mM SA	6.41a	15.16a	4.8a	3a	10b	3.56a	2.13a	3.04b
0.5 mM MJ+1 mM SA	6b	12.17b	4.3ab	2.46b	8.12c	3ab	1.63ab	2.96b
1 mM MJ+0.5 mM SA	6b	11.2b	4.41ab	2.51b	10.1b	3.12ab	1.2b	3b
1 mM MJ+1 mM SA	5.8b	12.18b	4.11ab	2.49b	12.3b	3.1ab	1.25b	3b

Means followed by same letter are not significantly different at 5% probability using Duncan's test.

DISCUSSION

As it has been indicated in Table 1, SA (1 mM) and MJ (1 mM) had reduced effects on plant height, dry weight, total N and K contents of tomato, if compared to SA (0.5 mM) and MJ (0.5 mM) . The exogenous application of MJ evoked major effects, indicating that MJ may be responsible for the decline in the growth related traits. These results are also consistent with Heijari *et al.,* (2005) who reported that seedling diameter, shoot fresh weight, root fresh weight and root length were hampered by MJ treatment in Scots pine. The MJ-induced loss of photosynthetic pigments would decrease the amount of energy absorbed by the photosynthetic apparatus, thereby attenuating energy requiring anabolic events such as photosynthesis (Zhang *et* *al.,* 2002). The MJ-treatment in the current study is in accordance with that of Jung (2004), who reported a significant loss of pigment contents due to MJ-treatment. However, vegetative factors were strongly inhibited by increasing MJ concentration. The current results are in harmony with those reported by Koda (1999). Salicylic acid (SA) is considered as a hormone-like substance, which plays an important role in the regulation of plant growth and development. Ion uptake and transport (Wang *et al.,* 2006), photosynthetic rate, membrane permeability and transpiration (Khan et al., 2003) could also be affected by SA application. In agreement with our results, Gharib (2006) on Basil and Yildırım and Dursun (2009) on tomato mentioned that lower SA concentration increased plant height, chlorophyll content, number of branches and leaves per plant and dry weight. Ertan *et al.,* (2008) reported that shoot diameter and leaf number per plant increased with salicylic acid treatments in cucumber grown under salt stress. The present results are in agreement with Sweify and Abdel-Wahid (2008), who found that application of SA increased chlorophyll a and b as well as carotenoids in *Syngonium podphyllum* plants. Moreover, salicylic acid significantly increased chlorophyll a & b and carotenoids (Zaki and Radwan, 2011). Singh and Singh (2008) reported that SA treatments at lower concentrations (50 µM) showed significant increase in chlorophyll content and total non-structural carbohydrate (TNC). However, higher concentrations have inhibitory effects.

The results in table 1 and 2 show that application of SA or MA or in combination significantly increased reproductive growth, yield and improved fruit quality, while The nitrate reductase activity was significantly reduced by the foliar application SA or MJ. Salicylic acid stimulates flowering in a range of plants, increases flower life, controls ion uptake by roots and stomatal conductivity (Bhupinder and Usha, 2003). Previous studies have demonstrated that a wide range of responses might appear after exogenous SA application as follows: yield increases, fruit weight and fruits per plant(El-Tayeb, 2005; Khodary, 2004; Yildirim *et al.*, 2008). Similar results were obtained by SA on broad bean and dry bean (Zaghlool *et al.,* 2001). In addition, foliar application of salicylic acid significantly increased yield and its components of maize (Abdel-Wahed *et al.*, 2006) and basil and marjoram plants (Gharib, 2006). The current result were dissimilar to that of Lolaei et al., (2013) who reported that fruit firmness decreased notably after MJ treatment. Altuntas et al. (2012) evaluated the physical and mechanical properties of Fuji apple as affected by methyl jasmonate treatments. As the MeJA doses increased from 1,120 to 4,480 mg L^{-1}, the skin firmness of apple linearly increased. The present findings are in agreement with the results obtained by Gonzalez-Aguilar *et al.,* (2004) who reported that application of MJ on guava caused an increase in TSS and a decrease in TA in fruit. Sayyari *et al.,* (2009) has shown that the amount of acidity and TSS was not influenced by SA treatment in pomegranate. Chandra *et al.,* (2007) reported that application of salicylic acid increased total soluble sugar and soluble protein of cowpea plants. In conclusion, Application of Methyl jasmonate (0.5 and 1 mM) alone or in combination significantly decreased, plant height, dry weight, chlorophyll, nitrate reductase activity and fruit weight. Salicylic acid application at low concentration (0.5 mM) significantly increased leaf N content, chlorophyll and dry weight, while reduced blossom end rot. In general, the combination of 0.5 mM MJ+0.5 mM SA significantly increased the TSS, pH, TA and vitamin C content. Application of 0.5 mM MJ+0.5 mM SA as foliar spray could be more profitable.

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تأثير الرش بحمض الساليساليك و ميثيل جاسمونات على الانتاج ومكونات الانتاج والخصائص الكيماوية للبندورة

محسن كاظمي*

ملخـــص

أجريت التجربة بهدف دراسة تأثير الرش بحمض الساليساليك وميثيل جاسمونات والتداخل بينهما على الإنتاج ومكونات الإنتاج والخصائص الكيماوية للبندورة. بينت النتائج أن الرش الورقي بحمض الساليساليك بتركيز 5و0 ملي مولر زاد النمو الخضري والزهري والإنتاجية وحسن من نوعية الثمار بينما انخفضت نسبة تعفن الطرف الزهري. في المقابل، أدى الرش بميثيل جاسمونات بتركيز 1 ملي مولر إلى نقصان النمو الخضري وزيادة النمو الزهري. بينما أدى الرش بحمض الساليساليك وميثيل جاسمونات معا بتركيز 5و0 ملي مولر لكل منهما إلى زيادة المواد الصلبة الذائبة، الحموضة المعايرة ومحتوى الثمار من فيتامين ج . يستنتج من البحث أن الرش بحمض الساليساليك و ميثيل جاسمونات معا بتركيز 5و0 ملي مولر يؤدي إلى زيادة الانتاجية وتحسين جودة الثمار في البندورة.

الكلمات الدالة: البندورة، حمض الساليساليك، ميثيل جاسمونات، النمو الخضري، النمو الزهري، الإنتاجية، جودة الثمار.

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