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**ORIGINAL ARTICLE**

# Effect of Foliar Application with Salicylic Acid and Methyl Jasmonate on Growth, Flowering, Yield and Fruit Quality of Tomato

**Mohsen Kazemi**
Department of Horticultural Science, Faculty of Agricultural Science and Natural Resources, Science and Research Branch, Islamic Azad University, Tehran, Iran
Corresponding author: E-mail: kazemimohsen85@gmail.com

**ABSTRACT**
*This experiment was conducted to study the effect of salicylic acid and methyl jasmonate as pre- harvest treatments on the tomato vegetative growth, yield and fruit quality. The experiment was completely randomized experimental design with four replications. These factors included salicylic acid in 2 levels (0.5 and 0.75 mmolL$^{-1}$) and methyl jasmonate in 3 levels (0.25, 0.5 and 0.75 mmolL$^{-1}$) applied on tomato. Results indicated that salicylic acid (0. 5 mmolL$^{-1}$) and methyl jasmonate (0.25 mmolL$^{-1}$) either alone or in combination (0.5 mmolL$^{-1}$ SA+ 0.25 mmolL$^{-1}$ MJ) increased vegetative and reproductive growth, yield and chlorophyll content. The application of salicylic acid (0. 5 mmolL$^{-1}$) alone significantly increased the leaves-NK content and dry weight and decreased the incidence of blossom end rot, but methyl jasmonate application alone or in combination had not significant effect on blossom end rot and leaves -NK content. The TSS, TA and vitamin C content of tomato fruit had significantly affected by the application of salicylic acid and methyl jasmonate either alone or in combination(0.5 mmolL$^{-1}$ SA+ 0.25 mmolL$^{-1}$ MJ). Application of salicylic acid with methyl jasmonate improved the yield contributing factors that resulted in significant increase in tomato fruit yield.*
***Key words**: tomato, growth, yield, fruit quality, salicylic acid, methyl jasmonate*
*Abbreviations: SA, Salicylic acid; MJ, methyl jasmonate; TSS, Total soluble solids; TA, Titratable acidity.*

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## INTRODUCTION

Tomato is one of the popular and most consumed vegetable in Iran. Production of quality tomato is controlled by the interaction of genetic, environmental, cultural factors growing substrate and nutrient solution composition in greenhouse [1]. Foliar feeding of vegetable plants can effectively supplement soil fertilization. It has been found that elements foliar application is in a same level and even more influential compared to soil application. It was suggested that foliar feeding could be applied successfully to compensate shortage of those elements [2]. According to Kołota and Osińska [3], foliar feeding is an effective method of supplying nutrients during the period of intensive plant growth when it can improve plants mineral status and increase crop yield. Salicylic acid, a naturally occurring plant hormone acting as an important signaling molecule adds to tolerance against abiotic stresses. It plays a vital role in plant growth, ion uptake and transport. SA has numerous functions, particularly the inhibition of germination and growth, interference with root absorption, reduced transpiration and leaf abscission [4]. Ion uptake and transport, photosynthetic rate, membrane permeability and transpiration [5] could also be affected by SA application. Khodary [6] found that SA treatment increased the chlorophyll and carotenoid contents in maize plants. Application of SA also significantly increased dry weights of root and top part of barley [7]. Fariduddin et al.[8] reported that the dry matter accumulation was significantly increased in *Brassica juncea*, when lower concentrations of salicylic acid were sprayed. Methyl jasmonate (MJ) is used as plant growth regulator in many fruits [9]. MJ is important cellular regulators involved in diverse developmental processes, such as seed germination, root growth, fertility, fruit ripening, and synthesis of ethylene, accumulation of anthocyanin and promotion of senescence [9]. Jung [10] reported the significant loss of pigment contents due to MJ-treatment. MJ applic ation might cause stomatal closure which inhibited $CO_2$ absorption and ultimately resulted in declined photosynthetic activity [11]. The MJ induced reduction of the gas-exchange traitsis in conformity with Rossato et al. [12], which revealed the inhibitory role of MJ on gas-exchange. The aim of the present study was the effects of foliar spraying of SA and MJ either alone or in combination on the growth, yield, fruit quality characteristics and blossom end rot incidence of tomato fruit.

## MATERIAL AND METHODS

The field experiment was conducted in 2012-2013 at the greenhouse complex 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, containing total N (2.4%), total C (1.35%), a C/N ratio of 0.45, 77, 114 mg·kg$^{-1}$ of P, and K, respectively, and with an EC of 0.078 ds·cm$^{-1}$. The aim of the experiment was to study the effect of 3 concentrations of MJ (0.25, 0.5 and 0.75 mmolL$^{-1}$) and 2 concentrations of SA (0.5 and 0.75 mmolL$^{-1}$) spray, on plant height, number of fruits per cluster, total yield, mean fruit weight, soluble solid content, total titrable acid, vitamine C, total nitrogen and potassium in fruits of tomato. \`Rada\` cultivar seeds were sown on 5 April 2012 in single plastic pots (12 × 11 cm) filled with white peat. Transplantation took place on 1 May 2012 into greenhouse, at a plant density of 3 plants per m$^2$ for the remainder of the experiment after soil plowing and disking. Plants were grown vertically, allowing the principal stem to grow. Spraying solutions were prepared with distilled water and sprayed three times during plant growth by 20 days between treatments with a sprayer. Temperature inside the greenhouse was controlled using automatic activation of the aerial heating fan with a TCL split type air condition-indoor unit system to maintain temperature between 25 and 16°C (day and night).

Leaf N content was determined by adopting the methods of Lindner [13]. Leaf K was measured with the help of a flame photometer. Lycopene in fruits was estimated as described by Sadasivam and Manikam [14]. The total yield for each treatment was calculated by weighing the fruit picked in each replication and converting the weight to Mg. ha$^{-1}$. The average fruit weight was estimated by weighing 10 fruits in each treatment, with the help of an electronic balance measuring in grams to the third decimal place, and then converting to average fruit weight. Sub-samples (10 g) were pressed through cheese cloth to extract the juice. Total soluble solids were determined on a portable refractometer (NC-1, Atago Co., Japan) standardized with distilled water. Total titrable acid and vitamine C was measured by NaOH (0.1 M) titration and indophenol's method according to Horvitz et al. [15]. Blossom end rot incidence (%) was estimated by counting the total number of fruits and fruits showing symptoms of blossom end rot in each treatment. The blossom end rot incidence is expressed as a percentage of total fruits. The fruit firmness was recorded with the help of a penetrometer. 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. Photosynthetic pigments chlorophyll was determined using chlorophyll meter (SPAD-502, Minolta Co. Japan), which is presented by SPAD value. Average of 3 measurements from different spots of a single leave was considered.

### Statistical Analysis

The experiment was completely randomized experimental design (CRD) with three replications. Data were analyzed by SPSS 16 software and and comparing averages was done by Duncan's test and a probability value of %5.

## RESULTS AND DISCUSSIONS

### *Vegetative and reproductive growth*

The results indicated that 0.25 mmolL$^{-1}$ MJ and 0.5 mmolL$^{-1}$ SA both caused a significant increase in vegetative and reproductive growth compared to other levels ($p \leq 0.05$). The interaction between MJ and SA (0.5 mmolL$^{-1}$ SA+ 0.25 mmolL$^{-1}$ MJ) on vegetative and reproductive growth was significant, as well (Table 1). The plant height increased to its maximum (105.11, 120.31 and 120.14 cm) with 25 mmolL$^{-1}$ MJ, 0.5 mmolL$^{-1}$ SA and 0.5 mmolL$^{-1}$ SA+ 0.25 mmolL$^{-1}$ MJ application, respectively (Table 1). The maximum number of fruits per plant (35.12) and number of flower per plant (7) was recorded with 0.5 mM MJ+0.5 mM SA application (Table 1). These results are also consistent with Heijari et al. [16] who reported seedling diameter, shoot fresh weight, root fresh weight and root length were hampered by low MJ concentration in Scots pine. Similar observations were reported by Zhang et al. [17]. However, morphological characters were strongly inhibited by increasing MJ concentration. Results similar reported by Koda, [18]. Salicylic Acid (SA) is a growth regulator which participates in the regulation of physiological processes in plants. It stimulates flowering in a range of plants, increases flower life, controls ion uptake by roots and stomatal conductivity [19]. Previous studies have demonstrated that a wide range of responses might appear after exogenous SA application as follows: height plant increases, fruit weight and fruits per plant [6-7]. Application of SA also significantly increased dry weights of root and top part of barley and soybeans[20]. The mechanism of salicylic acid was reported by Oata [21] and Pieterse and Muller [22] who concluded that salicylic acid induced flowering by acting as a chelating agent. This view was supported by Raskin et al. [23] who confirmed that salicylic acid functioned as endogenous growth regulators of flowering and florigenic effects.

***Chlorophyll, dry weight and Chemical Contents***

Application of high MJ and SA concentration caused a significant decrease in chlorophyll index and dry weight while MJ +SA combination had no significant effect (Table1). The maximum chlorophyll content (23.1 and 25 SPAD) and dry weight (6.89 and 6.97 g) was recorded with 0.5 mM SA and 0.25 mM MJ application (Table1). The leaves-NK content was not affected by application of MJ alone or in combination, but low SA (0.5 mmolL$^{-1}$) concentrations alone significant increasing leaves -NK content and chlorophyll content. Interaction between factors was not significant in chlorophyll, dry weight and chemical contents (Table1). The exogenous application of MJ evoked major effects; this indicates that MJ was responsible for the decline in the growth related traits. MJ-induced loss of photosynthetic pigments would decrease the amount of energy absorbed by the photosynthetic apparatus, thereby it could attenuate energy requiring anabolic events such as photosynthesis. MJ-treatment in our study is in accordance with Jung [10], who reported the significant loss of pigment contents due to MJ-treatment. In agreement with our results, [24] on basil and [25] on tomato mentioned that lower SA concentration increased plant height, chlorophyll content, number of branches, leaves per plant and dry weight. Application of high SA concentration negatively affected growth, photosynthesis and yield of mungbean [26]. Fariduddin et al. [9] reported that the dry matter accumulation was significantly increased in Brassica juncea, when lower concentrations of salicylic acid were sprayed. However, higher concentrations of salicylic acid had an inhibitory effect. Khodary [6] observed a significant increase in growth characteristic, pigment contents and photosynthetic rate in maize, which was sprayed with

**Table 1. Effect of MJ and SA on leaves-NK content, yield, number of fruits per plant,mean fruit weight, number of flower branch per plant, plant height,stem diameter of tomato**

| Treatments | Plant height (cm) | Number of flower branch per plant | Number of fruits per plant | Mean fruit weight (g) | Yield (Mg. ha$^{-1}$) | Chlorophyll (SPAD) | D. W. (g/100g F.W.) | N(%) | K(%) |
|---|---|---|---|---|---|---|---|---|---|
| **Control** | **72.11cd** | **2.64c** | **14.12c** | **66.02c** | **105.41c** | **19.21b** | **4.21b** | **2b** | **2.07b** |
| 0.25 mM MJ | 105.11ac | 6.14a | 25.6ab | 89.12b | 163.7a | 23.1a | 6.89a | 1.43c | 1.02c |
| 0.5 mM MJ | 100b | 5b | 20.1b | 75.36bc | 153.8ab | 10.36cd | 3.41c | 1.14c | 1.06c |
| 0.75 mM MJ | 92.12c | 5.14b | 19.69b | 72.14bc | 150.37ab | 10.32cd | 3.18c | 1.3c | 1.09c |
| 0.5 mM SA | 120.31a | 6.12a | 30.1a | 95.6a | 165.12a | 25a | 6.97a | 2.54a | 3a |
| 0.75 mM SA | 115.41ab | 5b | 24.12b | 70.12bc | 152.4ab | 10.63cd | 3.3c | 2b | 2.61b |
| 0.25 mM MJ+0.5 mM SA | 120.14a | 7a | 35.12a | 95.94a | 170.32a | 12.14c | 3c | 1.69c | 1.21c |
| 0.25 mM MJ+ 0.75 mM SA | 115.16ab | 4.36b | 21.14ab | 90.31b | 145.36ac | 12.13c | 2.89c | 1.41c | 1c |
| 0.5 mM MJ+ 0.5 mM SA | 113.14ab | 4b | 21ab | 86.14b | 143.12ac | 12c | 2.73c | 1.35c | 1.09c |
| 0.5 mM MJ+ 0.75 mM SA | 110.3ac | 3.59bc | 17.36ac | 85.39b | 140.36ac | 12.79c | 2.7c | 1.2c | 1c |
| 0.75 mM MJ+ 0.5 mM SA | 108.3ac | 3.14bc | 15.14b | 80.14bc | 139.65ac | 12.69c | 2.61c | 1.31c | 1.06c |
| 0.75 mM MJ+ 0.75 mM SA | 103.14ac | 3bc | 15.1b | 80bc | 139.3ac | 12.8c | 2.58c | 1.21c | 1.01c |

salicylic acid. These results are in line with many other researchers who reported an increased amount of almost all elements in roots and shoot with application of SA [27].

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

***Yield and fruit quality***

The results indicated that 0.25 mmolL$^{-1}$ MJ and 0.5 mmolL$^{-1}$ SA both caused a meanful increase in fruit quality compared to other levels ($p \leq 0.05$). The interaction between MJ and SA (0.5 mmolL$^{-1}$ SA+ 0.25 mmolL$^{-1}$ MJ) on fruit quality was significant (Table 2). On the other side, the interaction between MJ and SA on yield and fruit weight was significant (Table 1). Highest means of yield (170.32 Mg. ha$^{-1}$) and fruit weight (95.14 g) were found in tomato treated with 0.5 $mmolL^{-1}$ SA+ 0.25 $mmolL^{-1}$ MJ, followed by 165.12(Mg. $ha^{-1}$) and 85.6 (g) with 0.5 $mmolL^{-1}$ SA and 163.7 (Mg. $ha^{-1}$) and 89.12(g) with 0.25 $mmolL^{-1}$ MJ (Table 1). The maximum TSS (6 °Brix), TA (3.59 %) and vitamine C (15.14) was recorded with 0.5 $mmolL^{-1}$ SA+ 0.25 $mmolL^{-1}$ MJ applications. The blossom end rot was not affected by application of MJ alone or in combination, but SA application significant decreased blossom end in both (Table 2). The present findings are in agreement with the results obtained by Gonzalez-Aguilar et al. [28]. They reported application of MJ on guava caused increased T.S.S and decreased TA in fruit. Ayala-Zavala et al. [29] demonstrated that strawberry fruits treated with MJ were maintained higher level of TSS and PH. The fruit yield in cucumber and tomato, enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid [29]. It was reported that the foliar application of salicylic acid on soybean also enhanced the flowering and pod formation [30]. Sayyari et al. [31] has shown that the amount of acidity and TSS was influenced by SA treatment in pomegranate. Chandra et al. [1] (2007) reported that application of salicylic acid increased total soluble sugar and soluble protein of cowpea plants. In conclusion, foliar application of SA and MJ treatments were generally effective on vegetative growth, photosynthetic pigments, minerals, yield and quality of tomato fruit. SA foliar spraying at 0.5mM combined with MJ at 0.25mM being the most effective. However, further investigations are required to elucidate the possible role of SA and MJ on plant growth regulating activity.

**Table 2. Effect of MJ and SA on TSS, TA, vitamine C and Blossom end rot of tomato**

| Treatments | TSS (°Brix) | TA (%) | Vit. C (mg. 100 g fresh $fruit^{-1}$) | Blossom end rot (%) |
|---|---|---|---|---|
| **Control** | **2.12c** | **2c** | **8.12c** | **32.14a** |
| 0.25 mM MJ | 5.12a | 3.42a | 13.12a | 18b |
| 0.5 mM MJ | 4.67b | 3b | 10.4b | 18b |
| 0.75 mM MJ | 4.6b | 2.93b | 10b | 18.36b |
| 0.5 mM SA | 5.49a | 3.42a | 12.21a | 4.19c |
| 0.75 mM SA | 4.8b | 3b | 11.07b | 6.3c |
| 0.25 mM MJ+0.5 mM SA | 6a | 3.59a | 15.14a | 9.80b |
| 0.25 mM MJ+ 0.75 mM SA | 4.41b | 3.09ab | 10.14b | 10b |
| 0.5 mM MJ+ 0.5 mM SA | 4b | 3.05b | 11.14ab | 10b |
| 0.5 mM MJ+ 0.75 mM SA | 3.36bc | 3.01b | 10.21b | 10.31b |
| 0.75 mM MJ+ 0.5 mM SA | 3.36bc | 3b | 10.14b | 10.12b |
| 0.75 mM MJ+ 0.75 mM SA | 3bc | 3.04b | 10b | 10.09b |

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

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