STUDENT RESEARCH REPORT – REEU PROGRAM 2022

Effect of Jasmonic Acid on Tomato Fruit Quality

By: Lauren Ho[1], Mateo Rull-Garza[2], Amanda Kinchla[1], Jaime C. Piñero[2]

[1]Department of Food Science, [2]Stockbridge School of Agriculture

Abstract

Jasmonic acid (JA) and the jasmonates family are essential organic compounds often produced during plant growth and defense responses, which can be stimulated by biotic and abiotic stressors such as water stress, mechanical stress, or pathogenic stress. Additionally, jasmonates have been associated with enhancing the quality of some plants' fruit. Previous studies have shown that stressed tomato plants produce fruit of better quality, although the fruit yield is lower than in non-stressed plants. However, it is unclear whether the application of JA during cherry tomato development influences the quality of the fruit in terms of its size. Based on these parameters, I hypothesized that the application of JA enhances cherry tomato fruit quality, specifically the fruit's diameter and weight. To test this, tomato plants growing in the greenhouse at UMass Amherst were sprayed once every week during a 4-week span with three concentrations of JA (0.1mM, 1.0mM, 10mM), as well as a solvent control. The fruits' growth was then evaluated via weight and diameter. Because JA has been shown to increase fruit quality at the expense of yield, I predicted tomato plants treated with JA to possess a larger diameter and greater weight when compared to untreated tomato fruits. My study contributes to an understanding of the relationship between tomato stress responses and fruit quality, allowing growers to develop optimized growing practices.

Introduction

Plant stress is strongly associated with the growth and production yield of crops and fruits (Randome et al., 2017; Lida, 2014): past studies have shown that when plants experience a certain degree of stress they produce a higher yield of crops and better quality of fruits (Randome et al., 2017; Lida, 2014). Jasmonic acid (JA), as well as methyl jasmonate, a compound in the same family as JA, is commonly used in experiments on plant stress, as it is a compound released by the plant when it is stressed or is defending itself from biotic or abiotic factors, such as water deficiency or herbivore insects (Yang et al., 2019). Moreover, methyl jasmonate is also utilized pre-harvest period to improve the appearance and taste of fruits, such as apple, avocado, and raspberry, which increases the marketability and therefore value of the products (Reyes-Díaz et al., 2016). The treatment of methyl jasmonate on cherry tomato (*Solanum lycopersicum* L.) fruits postharvest has also been shown to enhance the content of essential nutrients, such as absorbic acid (vitamin C) and carotenoids (Liu et al., 2018).

In a study by Redman et al. (2001), the fruits from tomato plants (cv. "Burpee Big Boy") treated with JA were significantly larger, by an average of about 15 grams, than those in the other treatment groups (Redman and Schultz, 2001). Another recent study by Randome et al. (2017) conducted at the University of Pretoria also revealed that tomato plants treated with salt stress produced fruits 2.8 times higher in lycopene and 2.5-2.7 times higher in beta-carotene compared to other groups (Randome et al., 2017). Lycopene is fundamentally recognized as an antioxidant, found to be efficient in ameliorating cancer insurgences, diabetes mellitus, cardiac complications, oxidative stress-mediated malfunctions, inflammatory events, skin and bone diseases, hepatic, neural, and reproductive disorders; while beta-carotene is also well-known to be an antioxidant with known health benefits (Imran et al., 2020; Grune et al., 2010). In general, jasmonates are powerful, well-established promotors of fruit quality and size.

Although past studies have looked at both nutritional and size properties of cherry tomatoes treated with JA post-harvest, none have specifically looked at its effects on the fruit if sprayed during fruit development. In order to elucidate the effects of JA on fruit quality during the growing period, I investigated the way in which increasing concentrations of JA impacts the quality of the cherry tomato fruit, including its diameter and weight at harvest. Specifically, I hypothesized that sustained application of JA across cherry tomato fruit development increases the size (measured in terms of diameter and weight) of the fruit at harvest.

Materials and Methods

<u>Plant acquisition and growing conditions</u>. Twenty cherry tomato plants (variety Supersweet 100) were purchased from Atlas Farm in South Deerfield, MA. On the day of purchase, all the plants were in the flowering stage, around four weeks after initial planting. Tomato plants were then transplanted in 8-L plastic pots at the University of Massachusetts Amherst Morrill greenhouse. The plants were trimmed to 120 cm height, supported with cages, climb trellises, and stakes or ties, and were irrigated every day and supplemented with nutrients as needed.

<u>Jasmonic Acid application</u>. Purified Jasmonic Acid (JA) in liquid form was purchased from Sigma-Aldrich (Burlington, MA). The purified JA was then dissolved in 100% ethanol at three different concentrations: 0.1 mM, 1 mM, and 10 mM, while a control group was treated with the ethanol solvent only. Three mL of treatment solution were applied directly to the foliage of tomato plants weekly for four consecutive weeks using a mist spray bottle. The total quantity of JA applied per treatment plant is noted in Table 1.

Table 1. Concentrations of JA applied to tomato plants for each treatment and moles of JA treated per cherry tomato plant after a four-week spray.

	Group 1	**Group 2**	**Group 3**
Concentration (mM)	0.1	1	10
Moles per plant for each group (mmol)	0.0012	0.012	0.12

Fruit quality assessment. Tomato fruits were harvested throughout the treatment period and were harvested starting July 19 throughout August 16 as fruit acquired a deep red color on the vine. Fruits were preserved in a regular cooler. After picking the fruits, the diameter of 20 fruits from each group was taken using a Vernier caliper. The weight of the fruits was then measured and recorded with a scale.

Statistical Analyses. To compare diameter and weight measures from the multiple treatment groups, (i.e. the three different concentrations of JA and the control group), I ran analyses of variance (ANOVA) with post-hoc multiple comparison test in Statistica (StatSoft, Tulsa, OK).

Results

At harvest, I measured the fruit's diameter and found that jasmonic-acid treated plants bore fruits that were, overall, significantly smaller (ANOVA; $F_{3,76} = 5.76$, $p = 0.001$) than plants that were not treated with JA (Fig. 1). Specifically, fruits treated with 0.1 mM ($p = 0.002$), and fruits treated with 10 mM ($p = 0.001$) JA had a smaller diameter than control fruits. However, fruits treated with 1 mM JA were not significantly smaller than control fruits ($p = 0.3292$). A summary of significant differences between groups is shown in Table 2.

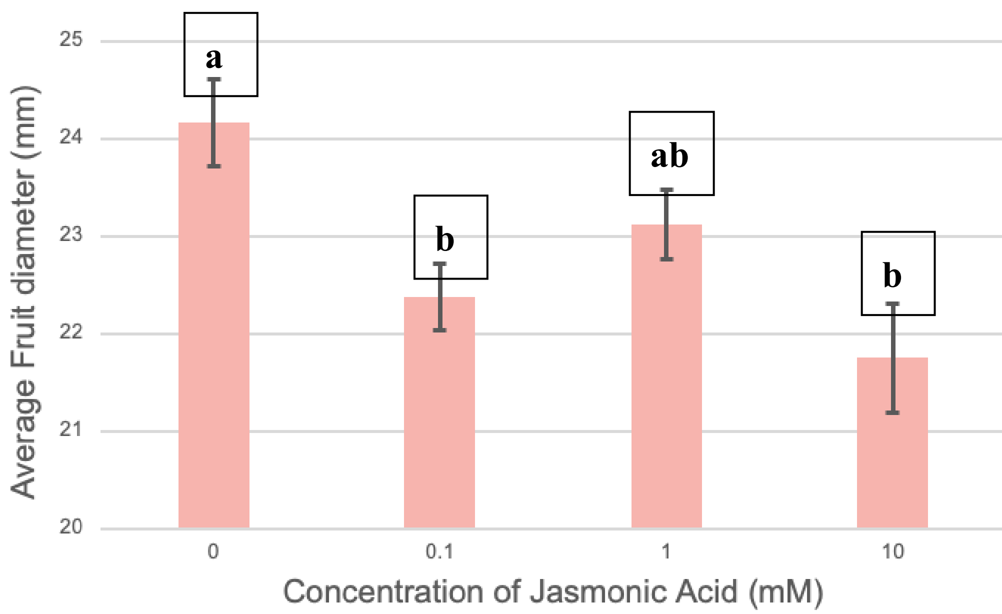

Figure 1. Diameter of cherry tomato (supersweet 100) at harvest across different Jasmonic Acid concentration**.** Box plot whiskers indicate positive and negative standard errors. Different letters indicate statistically significant differences between groups.

Table 2. Statistical analysis of cherry tomato diameter for multiple comparisons. Significant *p* values (P< 0.05) are highlighted in red and bold, indicating significant differences in diameter between treatment groups.

Treatment	Control	0.1 mM	1 mM	10 mM
Control		0.22937	0.329222	**0.00111**
0.1 mM	**0.022937**		0.613404	0.74062
1 mM	0.329222	0.613404		0.12173
10 mM	**0.00111**	0.74062	0.12173	

I then measured the weight fruits from JA-treated plants and found that, overall, they measured a significantly lighter weight (ANOVA; $F_{3,76} = 6.656$, $p < 0.001$) than plants that were not treated with JA (Fig. 2). Specifically, fruits treated with 0.1 mM ($p = 0.014$), and fruits treated with 10 mM ($p < 0.001$) JA had a lighter weight than control fruits. However, fruits treated with 1 mM JA were not significantly lighter than control fruits ($p = 0.322$). A summary of significant differences between groups is shown in Table 3.

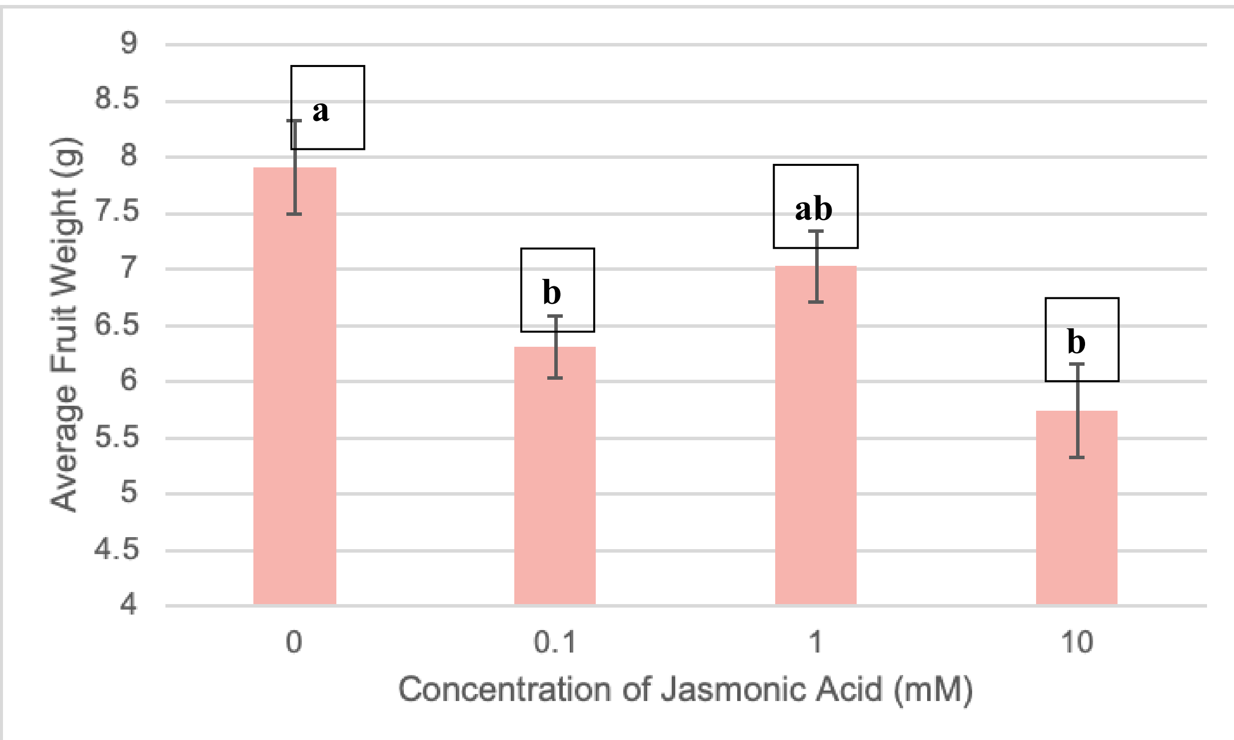

Figure 2. Weight of cherry tomato (supersweet 100) at harvest across different Jasmonic Acid concentrations**.** Box plot whiskers indicate positive and negative standard errors. Like letters represent grouped data with no significant differences between treatment groups. Different letters indicate statistically significant differences between groups.

Table 3. Statistical analysis of cherry tomato weight for multiple comparisons**.** Significant *p* values are highlighted in red and bold, and indicate significant differences in diameter between treatment groups.

Treatment	Control	0.1 mM	1 mM	10 mM
Control		**0.014024**	0.32202	**0.000499**
0.1 mM	**0.014024**		0.510885	0.677657
1 mM	0.32202	0.510885		0.066584
10 mM	**0.000499**	0.677657	0.066584	

Discussion

Many studies have shown that plant stress, including biotic and abiotic stress or the direct application of JA to the plant, has a positive impact on the quality of the fruit; in particular, the fruits can have better nutritional content and larger sizes (Lida, 2014, Randome et al., 2017). However, the effect of JA treatment during the fruiting period, specifically on the diameter and the weight of the fruit, has not been demonstrated. Based on past studies, I had hypothesized that plants treated with JA would produce bigger and heavier fruits. Across the experimental gradient, I expected that the 10 mM treatment plants would produce the fruit with the largest diameter and heaviest weight, while the control group will be the lowest.

To my surprise, the data on both diameter and weight contradict these initial predictions. In two out of the three treatment groups, tomatoes from control plants had a significantly larger diameter and heavier weight than fruits from JA-treated plants, with the exception of fruits from the 1mM plants (Group control: diameter = 24.17 mm, weight = 7.91 g; group 1 mM: diameter = 23.13 mm, weight = 7.02 g). However, in another study conducted by Nuruddin et al. (2003), water stress during flowering resulted in better yields and quality than stress at other developmental stages and in nonstressed plants. This may suggest that different stress methods or chemicals only apply to certain stages of tomato plants. For instance, methyl jasmonate, belonging to the jasmonate family, has been tested to improve the post-harvest life of many fruit crops (Reyes-Díaz et al., 2016).

My results also contradict the report by Redman and Schultz (2001), who found that plants treated with 10mM of JA produced significantly larger fruit than other treatment groups, including 1mM JA treatment and control groups. Overall, my data seems to suggest that the application of JA has a negative impact on fruit size.

On the one hand, the reason for these antagonistic effects does not lie on differences in JA application. In my study, the 10 mM group received 0.12 mmol of JA per plant (the 0.1 mM received 0.0012 mmol, and the 1 mM received 0.012 mmol per plant in total), which is 4 times larger than the amount of JA used per plant in the study conducted by Redman et al. (2001), in which the total moles used in their study were 0.003 mmol and 0.03 mmol (2001). However, our lowest concentration received 100 times less JA (approximately 0.001) than the 10 mM treatment and saw similar effects, so our concentration range was similar to Redman's study. On the other hand, the application period and frequency chosen in this study are different from Redman et al. (2001). While they applied JA on the tomato plants from the early stages of harvest and sprayed them once in two weeks, I treated the cherry tomato plants during the flowering, fruiting, and harvest stage and sprayed once a week. The period and frequency of our JA application may thus not be optimal for promoting fruit size.

Each fruit crop or varieties are possible to have different JA concentration preferences. In Reyes-Díaz et al.'s 2016 report, the researchers have shown that doses and application methods of methyl jasmonate in various fruit crops are different in order to inhibit fungal disease. For the purpose of this study, I used cherry tomato (cv. supersweet 100) while applying the same concentration of JA as Redman and Schultz's experiment, in which they used the cultivar "Burpee Big Boy". Therefore, it may be that concentration of JA used in this experiment, or the application methods, are simply not suitable for this variety of cherry tomatoes.

During the experiment, confounding stress factors were not completely eliminated. For instance, the plants were transported within the greenhouse to be pruned every week, but some plants were moved more than others and into spaces with less sunlight, which may induce more stress. All of the twenty cherry tomato plants were also infected by an unknown disease or sickness that was preliminarily identified as a calcium deficiency. The plants were then applied 15-5-15 Cal Mag fertilizer at 250 ppm N and given some extra calcium to combat the disease.

The developmental stage of the tomato plants used in this study also may influence the results. Since they were purchased during the flowering stage, it is unknown whether they had already been treated or managed somehow. By contrast, many researchers in similar past studies have grown the tomato plants directly from the seed (Liu et al., 2018; Redman and Schultz, 2001). Another external factor that may impact the final results is that the number of fruits from each tomato plant varied, although only 20 of the tomatoes from each group were arbitrarily chosen to assess size.

Future research may focus on finding an optimal amount of JA applied, application methods, and frequency of application (Yang et al., 2019) since several studies have shown that while the quality of the fruits may be better, the marketable yield is reduced (Nuruddin et al., 2003; Redman and Schultz, 2001). Also, it is important to also consider the nutritional value of the tomato, such as vitamin C, lycopene, and beta carotene, and the sensory aspects, such as sugar-acid ratio (Nuruddin et al., 2003; Randome et al., 2017). Although the benefit of JA application on fruit quality is positive, the price of JA is costly; therefore, there is a need to investigate pathways to either extract the compound inexpensively from plants or find alternative stressors, such as water, salt, or mechanical stress (Randome et al., 2017; Van Moerkercke et al., 2019).

Conclusion

I found that there is no improvement in the size of cherry tomato fruits harvested from plants treated with Jasmonic Acid. Our data contradict the view that stress induced by JA treatment can have a positive impact on the fruit size (and therefore quality) of cherry tomato plants. Investigating how plant stress (specifcially the application of JA during the fruiting period) affects the fruit size can give us more insights about optimal growing practices, considering that not all tomato varieties seem to respond positively to JA application.

References

Grune, Tilman, Georg Lietz, Andreu Palou, A. Catharine Ross, Wilhelm Stahl, Guangweng Tang, David Thurnham, Shi-an Yin, and Hans K. Biesalski. 2010. “β-Carotene Is an Important Vitamin A Source for Humans123.” The Journal of Nutrition 140 (12): 2268S-2285S. https://doi.org /10.3945/jn.109.119024.

Iida, Hidetoshi. 2014. “Mugifumi, a Beneficial Farm Work of Adding Mechanical Stress by Treading to Wheat and Barley Seedlings.” Frontiers in Plant Science 5 (September): 453. https://doi.org /10.3389/fpls.2014.00453.

Imran, Muhammad, Fereshteh Ghorat, Iahtisham Ul-Haq, Habib Ur-Rehman, Farhan Aslam, Mojtaba Heydari, Mohammad Ali Shariati, et al. 2020. “Lycopene as a Natural Antioxidant Used to Prevent Human Health Disorders.” Antioxidants 9 (8): 706. https://doi.org/10.3390 /antiox9080706.

Liu, Haoran, Fanliang Meng, Huiying Miao, Shanshan Chen, Tingting Yin, Songshen Hu, Zhiyong Shao, et al. 2018. “Effects of Postharvest Methyl Jasmonate Treatment on Main Health-Promoting Components and Volatile Organic Compounds in Cherry Tomato Fruits.” Food Chemistry 263 (October): 194–200. https://doi.org/10.1016/j.foodchem.2018.04.124.

Nuruddin, Molla, Chandra Madramootoo, and Georges Dodds. 2003. “Effects of Water Stress at Different Growth Stages on Greenhouse Tomato Yield and Quality.” HortScience: A Publication of the American Society for Horticultural Science 38 (December): 1389–93. https://doi.org /10.21273/HORTSCI.38.7.1389.

Randome, Ipeleng, Supratim Basu, and Andy Pereira. 2017. “Effect of Different Stress Treatments on Mature Green Tomatoes (Solanum Lycopersicum) to Enhance Fruit Quality.” AFRICAN JOURNAL OF FOOD, AGRICULTURE, NUTRITION AND DEVELOPMENT 17 (November): 12546–56. https://doi.org/10.18697/ajfand.80.16550.

Redman, Ahnya M., Donald F. Cipollini Jr., and Jack C. Schultz. 2001. “Fitness Costs of Jasmonic Acid-Induced Defense in Tomato, Lycopersicon Esculentum.” Oecologia 126 (3): 380–85.

Reyes-Díaz, Marjorie, Tomas Lobos, Liliana Cardemil, Adriano Nunes-Nesi, Jorge Retamales, Laura Jaakola, Miren Alberdi, and Alejandra Ribera-Fonseca. 2016. “Methyl Jasmonate: An Alternative for Improving the Quality and Health Properties of Fresh Fruits.” Molecules (Basel, Switzerland) 21 (6): E567. https://doi.org/10.3390/molecules21060567.

Tigist, M., Tilahun Seyoum Workneh, and Kebede Woldetsadik. 2013. “Effects of Variety on the Quality of Tomato Stored under Ambient Conditions.” Journal of Food Science and Technology 50 (3): 477–86. https://doi.org/10.1007/s13197-011-0378-0.

Van Moerkercke, Alex, Owen Duncan, Mark Zander, Jan Šimura, Martyna Broda, Robin Vanden Bossche, Mathew G. Lewsey, et al. 2019. A MYC2/MYC3/MYC4-Dependent Transcription Factor Network Regulates Water Spray-Responsive Gene Expression and Jasmonate Levels. Proceedings of the National Academy of Sciences 116 (46): 23345–56. https://doi.org/10.1073 /pnas.1911758116.

Yang, Jing, Guihua Duan, and Chunqin Li. 2019. The Crosstalks Between Jasmonic Acid and Other Plant Hormone Signaling Highlight the Involvement of Jasmonic Acid as a Core Component in Plant Response to Biotic and Abiotic Stresses. October. https://www.frontiersin.org/articles/10.3389/fpls.2019.01349/full.