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Jasmonate and salicylic sprays improve cherry tomato fruit productivity and quality in unheated greenhouses*

Pulverizaciones con jasmonato y salicílico mejoran la productividad y calidad de los frutos de tomate cherry en invernadero sin calefacción

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Abstract

Introduction. Arable regions often lack sufficient soil nutrients, which means that fertilizers must be used. However, using fertilizers excessively can harm the environment, human health and food safety. Natural growth regulators derived from plants are environmentally friendly and reasonably priced. The phytohormones methyl jasmonate (MeJA) and salicylic acid (SA) are crucial for enhancing plant biomass, quality, productivity and resistance to environmental stresses. **Objective.** To evaluate the foliar effect of MeJA and SA on fruit quality and production of colorful tomato cultivars under greenhouse conditions. **Materials and methods.** The trial was conducted at the University of Diyala, Iraq, from December 1, 2022, to June 5, 2023. Foliar applications of 0 mg/L, 200 mg/L SA and 200 mg/L MeJA were evaluated to determine their effects on fruit quality and production of colorful indeterminate cherry tomato cultivars: LA4013, LA353, LA2921, LA3899 and IQ2. A randomized complete block design was used, with each treatment having three replicates. **Results.** The cultivar IQ2 produced the heaviest fruit (82.13 g), the highest plant yield (4.56 kg/plant), the highest total yield (4.56 t/house) and the highest titratable acidity (0.62 %). The cultivar LA4013 had the highest fruit number (612.88 fruits/plant) and the highest total soluble solids (2.933 %). The foliar application of 200 mg/L SA resulted in the highest chlorophyll index (36.68 SPAD), the highest fruit number (373.73 fruits/plant), the highest plant yield (3.15 kg/plant) and the highest total yield (3.93 t/house). **Conclusion.** Considering all variables together, the best-performing genotypes were IQ2 and LA4013, which were superior to other genotypes in quality and yield trials. The foliar application of 200 mg/L SA improved both yield and quality of cherry tomatoes under greenhouse conditions.

Keywords: *Solanum lycopersicum*, breeding, genotype, phytohormones, plant growth, total soluble solids.

Resumen

Introducción. Las regiones cultivables a menudo carecen de nutrientes suficientes en el suelo, por lo que es necesario utilizar fertilizantes. Sin embargo, el uso excesivo de fertilizantes puede dañar el medioambiente, la salud humana y la seguridad alimentaria. Los reguladores de crecimiento naturales derivados de plantas son respetuosos con el medioambiente y tienen un precio razonable. Las fitohormonas jasmonato de metilo (MeJA) y ácido salicílico (SA) son cruciales para mejorar la biomasa vegetal, la calidad, la productividad y la resistencia a tensiones ambientales. **Objetivo.** Evaluar el efecto foliar de MeJA y SA sobre la calidad y la producción de frutos de cultivares de tomate en condiciones de invernadero. **Materiales y métodos.** La prueba se llevó a cabo en la Universidad de Diyala, Irak, del 1 de diciembre de 2022 al 5 de junio de 2023. Se evaluaron aplicaciones foliares de 0 mg/L, 200 mg/L de SA y 200 mg/L de MeJA para determinar los efectos sobre calidad de fruto y la producción cultivares de tomate *cherry* de crecimiento vegetativo indeterminado: LA4013, LA353, LA2921, LA3899 e IQ2, con un diseño de bloques completos al azar y tres repeticiones por tratamiento. **Resultados.** El cultivar IQ2 produjo la fruta más pesada (82,13 g), el mayor rendimiento por planta (4,56 kg/planta), el mayor rendimiento total (4,56 t/invernadero) y la mayor acidez titulable (0,62 %). El cultivar LA4013 presentó el mayor número de frutos (612,88 frutos/planta) y el mayor contenido de sólidos solubles totales (2,933 %). La aplicación foliar de SA a 200 mg/L resultó en el índice de clorofila más alto (36,68 SPAD), el mayor número de frutos (373,73 frutos/planta), el mayor rendimiento por planta (3,15 kg/planta) y el mayor rendimiento total (3,93 t/invernadero). **Conclusión.** Al considerar todas las variables en conjunto, los mejores genotipos fueron IQ2 y LA4013, los cuales resultaron superiores a los demás genotipos en los ensayos de calidad y rendimiento. La aplicación foliar de SA a 200 mg/L mejoró el rendimiento y la calidad de los tomates *cherry* en condiciones de invernadero.

Palabras clave: *Solanum lycopersicum*, mejoramiento genético, genotipo, fitohormonas, crecimiento vegetal, sólidos solubles totales.

Introduction

Cherry tomatoes (*Solanum lycopersicum* L. var. *cerasiforme*) are consumed widely around the world due to their bright color, distinctive scent, flavor, sweetness, nutritional value and massive health advantages (Chen et al., 2022; Simonne et al., 2008). The red pigment, which is high in the carotenoid lycopene, is a powerful antioxidant that shields cells from damage and lowers the risk of cancer (Gerszberg & Hnatuszko-Konka, 2017; Simonne et al., 2007). The attractiveness of cherry tomatoes, such as their color, shape and size, as well as their durability and shelf life, are key determinants of their quality. In addition, the organoleptic quality of tomatoes depends on physical characteristics like texture, and biochemical characteristics like the presence of sugars, acids and other volatile components (Chakma et al., 2021).

The performance qualities of the same genotype of tomato may differ under different growing conditions. The way a plant reacts to fertilizer is genotype dependent (Hamdi, 2022). The negative consequences of over-fertilization on soil nutrients and subsequently on crop yields can be avoided with the use of proper fertilization techniques (Al-Shammari & Hamdi, 2023). The communication between the root and shoot systems, as well as the regulation of the expression of several aquaporins, including plasma membrane intrinsic proteins, are ways in which plant hormones may respond to stress and help plants coordinate their growth (Al-Shammari & Hamdi, 2022; Farooq et al., 2009; Singhal et al., 2016; Zhu, 2016).

Over the past several years, numerous studies have shown how various biostimulants may interact in several ways, including by modifying one another's production and affecting signaling pathways in plant physiology (Altaf et al., 2022; Khalloufi et al., 2017). According to one theory, the interplay of biostimulants influences plant physiology synergistically and plays a key role in regulating plant growth and development through the control of physiological and biochemical traits, secondary metabolites, division and elongation of cells and protein synthesis (Ozturk & Unal, 2023; Raza et al., 2023; Tonelli et al., 2023), all of which are regulated by plant growth hormones under abiotic stress (Arshad et al., 2023; Borysiuk et al., 2022).

Methyl jasmonate (MeJA) and its derivatives are together referred to as jasmonates (JAs). It is an organic substance created by a series of enzymes found in the plastid, peroxisomes and the cytoplasm's octadecanoid acid (Environmental Protection Agency, 2013). JAs are oxylipin-type plant hormones first identified as a signal associated with wounds and that control several physiological, morphological and biochemical processes in plants (Pascual et al., 2023; Zhang & Huang, 2013). JAs play a role in the growth of roots, stamens and flowers; the senescence of leaves; the anthocyanin biosynthesis, and the photosynthetic carbon fixation (Qin et al., 2024). JAs also protect plants from the toxicity of heavy metals by coordinating ion transport (Ali & Ohri, 2023). MeJA has both synergistic and antagonistic relationships with other phytohormones, which significantly reduces the negative effects of biotic and abiotic stress (Alwan, Hamdi & Maleh, 2023). The use of JAs to enhance growth mechanisms in tomatoes is still novel and needs more research, as it might help farmers produce crops of higher quality and quantity by having a better understanding of metabolic pathways (Yu et al., 2022).

Salicylic acid (SA) is a phenolic molecule well demonstrated to contribute to both local and systemic plant defense responses against pathogens and environmental challenges such as salt, heavy metals, drought, cold, heat and UV exposure (Kaya et al., 2023). Seed germination, synthesis of chlorophyll and stomata closure are also influenced by SA (AL-Surhanee, 2022; Li et al., 2022). Reactive oxygen species (ROS) serve as internal signal molecules for the signal transduction process, and they control the oxidative burst during hypersensitive reactions to stress (Wang et al., 2020). As a result of inhibiting antioxidant enzyme activities, SA can cause the buildup of ROS in response to abiotic stress circumstances (Fan et al., 2022). The rising ROS level then acts as a secondary stress signal to activate cellular defense mechanisms such as enzymatic and non-enzymatic activities (García-Caparrós et al., 2021).

The objective of this study was to evaluate the foliar effect of MeJA and SA on fruit quality and production of colorful tomato cultivars under greenhouse conditions.

Materials and methods

The trial was carried out in the greenhouse in the Department of Horticulture and Landscape Gardening, University of Diyala, Iraq, during the 2022-2023 cropping season from December 1 to June 5, for a total duration of 18 weeks from seedlings. The chemical properties of the soil are as follows: soil texture, silty sandy loam; pH, 7.40; electrical conductivity, 0.7 dS; calcium carbonate, 6 %; organic matter, 1.50 %; available nitrogen (N), phosphorus (P) and potassium (K) were 30.80, 6.90 and 23 mg/kg, respectively. The soil content elements were measured according to Ostrowska et al. (1991) and the soil samples were taken before cultivation at a depth of 0.3 m.

The genetic material used was four genotypes of cultivated cherry tomato (LA4013, LA353, LA2921, LA3899) from the CM Rick Tomato Genetic Resources Centre (TGRC), University of California, USA, as well as IQ2 sourced from Iraq. These indeterminate genotypes have the potential for high yield and water stress tolerance.

Cherry tomato seedlings were raised on plastic seed trays filled with peat moss as a medium. After 25 days of seedling emergence at about the 3-4 leaf stages, uniformly vigorous seedlings were transplanted to the field on December 1, 2022. Poultry manure was added at a rate of 8 metric tons per hectare to the soil within each block before two weeks of transplantation. Before the plants were planted, each treatment plot's planting ridges received an initial application of a base fertilizer that contained P fertilizers (superphosphate) and K fertilizers; the sources were K_2SO_4 at 150 kg/ha. Each plot was occupied by a particular genotype of rows of plants (15 plants per plot) in an area of 1.2 m inter-row spacing and 0.45 m plant spacing. A distance of 1 m between alleys was maintained between plots, and the plots were laid out in a randomized complete block design by two factors (five cultivars in the first factor and three doses; 0 mg/L, 200 mg/L SA, or 200 mg/L MeJA as a foliar spray) with three replicates. MeJA and SA were obtained from Duchefa Biochemie, Haarlem, Netherlands. To avoid rapid drying of solutions,

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all applications were made in the early morning using a manual pressure sprayer, covering the plant leaves until they ran off.

The plants were trained vertically. Trailing, lateral stem and basal leaf trimming procedures were performed on a regular basis. Irrigation was done using a drip irrigation system with pressure-compensated 4 L/h emitters, supplied to maintain excess drainage no higher than 20 %. Field capacity irrigation was applied to all treatments. Chromotropic traps were used to monitor the main pests, also contributing to integrated pest management.

Fruit harvest began on April 20 and ended on June 5 when the fruits reached ripeness. Data were collected from five plants in each replicate of each plot. The chlorophyll index was evaluated with a chlorophyll meter (model 502, Minolta, Osaka, Japan). The number of fruits per plant was counted. The total number of mature fruits was weighed with an electronic weighing balance, and the fruit weight per plant was recorded. plant yield. The total fruit yield per house was estimated. The total soluble solids (TSS) were determined using a handheld refractometer (Brixstix BX 100 Hs; Technique Corporation, Livermore, CA). Titratable acidity (TA) was determined by potentiometric titration with 0.1 M NaOH to pH 8.1 using 10 mL of juice. The results were expressed as a percentage of citric acid in the juice (Ranganna, 1977).

Data were statistically evaluated with factorial analysis of variance with the SAS software (ver. 9.4, SAS, Inc., Cary, NC), using genotypes as fixed factors and rate of phytohormones application: salicylic acid and methyl jasmonate as a quantitative factor. In this analysis, both the effect of each factor on the various parameters studied and the possible interaction between the factors were analyzed. Statistically different groups were determined using least significant differences following Tukey's post hoc test ($p < 5$ %).

Results

In general, the main effects of genotype and phytohormones concentration (SA and MeJA) affected all measured traits. In addition, all other traits were affected by the 2-way interaction, except for plant yield and total yield (Table 1).

The genotype-affected values for all measured traits varied (Table 2). LA353 had the highest relative chlorophyll content (51.32 SPAD). LA4013 produced the highest number of fruits and TSS, which were 612.88 fruits/plant and 2.93 %, respectively. IQ2 produced the highest fruit weight (82.13 g), plant yield (4.56 kg/plant) and total yield (4.56 t/house). For the TA, both LA2921 and IQ2 were the best, with values of 0.59 and 0.62 %, respectively, compared with other genotypes.

Spray application of phytohormones had an effect on all measured traits (Table 3). Plants treated with 200 mg/L SA had the highest relative chlorophyll content (36.68 SPAD), number of fruits per plant (373.73), fruit weight (21.98 g), plant yield (3.15 kg/plant) and total yield (3.93 t/house). Most total soluble solids were produced due to treatment with both SA and MeJA, but SA produced the highest value, which was 1.93 %. The highest value for titratable acidity was produced with both treatments (0 mg/L or 200 mg/L SA), which were 0.55 %, compared with other treatments.

The interaction values among genotypes and the addition of phytohormones to all measured variables varied (Table 4). The cultivar LA353 treated with 200 mg/L SA had the highest content of chlorophyll in leaves (52.73 SPAD). The highest number of fruits per plant (615.00) was produced on LA4013 with the use of MeJA at 200 mg/L. The cultivar IQ2 treated with 200 mg/L MeJA produced the highest fruit weight (83.66 g), plant yield (5.18 kg/plant), total yield (6.47 t/house) and titratable acidity (0.66 %). The cultivar LA4013 treated with 200 mg/L SA produced the highest total soluble solids (3.10 %), compared with other treatments.

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Table 1. Analysis of variance for the main effects of genotype and spray application of phytohormones and the interaction between them, on chlorophyll index, number and weight of fruit, yield, total yield, total soluble solids and titratable acidity traits for cherry tomato plants *Solanum lycopersicum* L. var. *cerasiforme*. Conducted at the Research Station of the Department of Horticulture and Landscape Gardening, University of Diyala, Baqubah, Iraq, from December 1, 2022, to June 5, 2023.

Cuadro 1. Análisis de varianza para los principales efectos del genotipo y la aplicación por aspersión de fitohormonas y la interacción entre ellos sobre el índice de clorofila, número y peso del fruto, rendimiento, rendimiento total, sólidos solubles totales y características de acidez titulable para plantas de tomate *cherry Solanum lycopersicum* L. var. *cerasiforme*. Realizado en la Estación de Investigación del Departamento de Horticultura y Paisajismo de la Universidad de Diyala, Baqubah, Irak, del 1 de diciembre de 2022 al 5 de junio de 2023.

Source of variation	DF	Chlorophyll (SPAD)	No. fruits per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	TSS (%)	TA (%)
Replication								
(R)	2	0.03	0.01	12.60	6.48	20.68	0.01	0.001
Genotype								
(G)	4	10445**	11.83**	411075**	7.229**	726.1**	3.62**	0.03**
Foliartal								
(F)	2	5.78**	0.91**	921.6**	269.7**	345.4**	0.28**	0.003*
G×F	8	1.19**	0.09**	112.0*	6.33	2.71	0.38**	0.003**
Error	28	0.04	0.01	47.41	3.29	4.45	0.034	0.0001
Total	44							

**, * = Significant at 1 % or 5 % level of probability. / **, * Significativo al nivel de probabilidad del 1 % o 5 %.
TSS: Total soluble solids. TA: Titratable acidity. / TSS: Sólidos solubles totales. TA: Acidez titulable.

Table 2. Effect of genotypes on chlorophyll index, number and weight of fruit, yield, total yield, total soluble solids and titratable acidity traits for cherry tomato plants *Solanum lycopersicum* L. var. *cerasiforme*. Conducted at the Research Station of the Department of Horticulture and Landscape Gardening, University of Diyala, Baqubah, Iraq, from December 1, 2022, to June 5, 2023.

Cuadro 2. Efecto de los genotipos sobre el índice de clorofila, número y peso del fruto, rendimiento, rendimiento total, sólidos solubles totales y características de acidez titulable para plantas de tomate *cherry Solanum lycopersicum* L. var. *cerasiforme*. Realizado en la Estación de Investigación del Departamento de Horticultura y Paisajismo de la Universidad de Diyala, Baqubah, Irak, del 1 de diciembre de 2022 al 5 de junio de 2023.

Genotype	Chlorophyll (SPAD)*	No. fruits per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	TSS (%)	TA (%)
LA4013	34.08c	612.88a	4.62d	2.77c	3.47c	2.93a	0.47c
LA353	51.32a	331.66c	9.14b	3.02b	3.77b	1.42d	0.48c
LA2921	31.14d	317.22d	8.36c	2.67d	3.33c	1.62bc	0.59a
LA3899	25.20e	513.22b	2.63e	1.34e	1.68d	1.44cd	0.57b
IQ2	37.60b	55.33e	82.13a	4.56a	4.56a	1.63b	0.62a

* Values in columns followed by the same letter are not significantly different, $p < 0.05$, Tukey's HSD test. / * Los valores en las columnas seguidos de la misma letra no son significativamente diferentes, $p < 0{,}05$, prueba HSD de Tukey.
TSS: Total soluble solids. TA: Titratable acidity. / TSS: Sólidos solubles totales. TA: Acidez titulable.

Table 3. Effect of spray application of phytohormones on chlorophyll index, number and weight of fruit, yield, total yield, total soluble solids and titratable acidity traits for cherry tomato plants *Solanum lycopersicum* L. var. cerasiforme. Conducted at the Research Station of the Department of Horticulture and Landscape Gardening, University of Diyala, Baqubah, Iraq, from December 1, 2022, to June 5, 2023.

Cuadro 3. Efecto de la aplicación por aspersión de fitohormonas sobre el índice de clorofila, número y peso del fruto, rendimiento, rendimiento total, sólidos solubles totales y características de acidez titulable para plantas de tomate c*herry Solanum lycopersicum* L. var. cerasiforme. Realizado en la Estación de Investigación del Departamento de Horticultura y Paisajismo de la Universidad de Diyala, Baqubah, Irak, del 1 de diciembre de 2022 al 5 de junio de 2023.

Foliartal (200 mg/L)	Chlorophyll (SPAD)*	No. fruits per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	TSS (%)	TA (%)
0	34.72c	358.06c	20.47c	2.68c	3.34c	1.66b	0.55a
SA	36.68a	373.73a	21.98a	3.15a	3.93a	1.93a	0.55a
MeJA	36.20b	366.40b	21.42b	2.79b	3.47b	1.84a	0.53b

* Values in columns followed by the same letter are not significantly different, $p < 0.05$, Tukey's HSD test. / * Los valores en las columnas seguidos de la misma letra no son significativamente diferentes, $p < 0{,}05$, prueba HSD de Tukey.
TSS: Total soluble solids. TA: Titratable acidity. / TSS: Sólidos solubles totales. TA: Acidez titulable.

Table 4. Effect of the interaction between genotype and spray of phytohormones on chlorophyll index, number and weight of fruit, yield, total yield, total soluble solids and titratable acidity traits for cherry tomato plants *Solanum lycopersicum* L. var. cerasiforme. Conducted at the Research Station of the Department of Horticulture and Landscape Gardening, University of Diyala, Baqubah, Iraq, from December 1, 2022, to June 5, 2023.

Cuadro 4. Efecto de la interacción entre el genotipo y la aspersión de fitohormonas sobre el índice de clorofila, número y peso del fruto, rendimiento, rendimiento total, sólidos solubles totales y características de acidez titulable para plantas de tomate cherry *Solanum lycopersicum* L. var. cerasiforme. Realizado en la Estación de Investigación del Departamento de Horticultura y Paisajismo de la Universidad de Diyala, Baqubah, Irak, del 1 de diciembre de 2022 al 5 de junio de 2023.

Factors								
Genotype	Foliartal (200 mg/L)	Chlorophyll (SPAD)*	No. fruits per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	TSS (%)	TA (%)
LA4013	0	34.83ea	609.66a	4.33i	2.63fg	3.29gf	2.70c	0.52ed
	SA	32.06f	614.00a	4.60hi	2.67fge	3.34gef	3.10a	0.44g
	MeJA	35.36e	615.00a	4.93h	3.02d	3.77d	3.00b	0.46f
LA353	0	47.60b	324.66e	8.63f	2.80ef	3.49ef	1.20hg	0.45f
	SA	52.73a	332.33ed	9.13e	3.03d	3.78d	1.40ghf	0.48ef
	MeJA	35.63e	338.00d	9.66d	3.24c	4.04c	1.66ed	0.49ef
LA2921	0	28.30gh	309.00f	8.06g	2.60g	3.25g	1.76d	0.57cd
	SA	27.10h	312.00f	8.26g	2.57g	3.21g	1.50gdf	0.61bc
	MeJA	38.03d	330.66ed	8.76f	2.83e	3.53e	1.60edf	0.61bc
LA3899	0	28.40g	495.66c	2.40k	1.18i	1.48i	1.13h	0.61bc
	SA	25.06h	521.00b	2.63jk	1.36h	1.70h	1.10i	0.55d
	MeJA	22.13i	523.00b	2.86j	1.49h	1.86h	2.10c	0.55d
IQ2	0	34.46e	51.33h	80.26c	4.17b	5.21b	1.50dg	0.63ab
	SA	44.06c	52.66g	82.46b	4.33b	5.32b	2.10c	0.56cd
	MeJA	34.26e	62.00g	83.66a	5.18a	6.47a	1.30ghf	0.66a

* Values in columns followed by the same letter are not significantly different, $p < 0.05$, Tukey's HSD test. / * Los valores en las columnas seguidos de la misma letra no son significativamente diferentes, $p < 0{,}05$, prueba HSD de Tukey.
TSS: Total soluble solids. TA: Titratable acidity. / TSS: Sólidos solubles totales. TA: Acidez titulable.

Discussion

Productivity and fruit quality traits of tomatoes varied dramatically according to genotypes. This might be attributed to the genotypic variation between the five tomato cultivars and to the genetic factors intrinsic among genotypes (Hamdi, 2017), being little affected by environmental factors (Alwan & Mohammed, 2023) and abilities to absorb nutrients through leaves (Abood et al., 2019). A feature that is desirable in tomato breeding programs. Godoy et al. (2022) reported values of 4.50 fruits per plant, 117.59 g fruit weight, 4.67 kg yield per plant and 4.32 % TSS in tomato with indeterminate habit; other studies conducted by Al-Mfargy & Al-Juwari (2023) in indeterminate tomatoes reported values for fruit number per plant, fruit weight and plant yield of 512.32, 8.41 g and 2.72 kg, respectively.

The observed rise in yield in this study could be attributed to the enhanced content of chlorophyll in leaves, which increased dry matter resulting from the application of MeJA treatment. The differences observed among the five genotypes could be due to differences in each cultivar's sensitivity to MeJA (Alwan, Al-Zuhairy & Badri, 2023). These results obtained in this study are agree with Al-Shammari & Hamdi (2021), who reported a yield of 3.94 kg/plant in tomato lines of indeterminate growth. The findings show that there are promising tomato lines for yield characteristics and fruit quality, which are of great importance for breeding programs. These lines could be registered as a new variety or provide farmers with basic seed for them to carry out their own breeding programs.

In other lines, studies involving a broader spectrum of genotypes, including modern, traditional and non-domesticated species, have reported a wider variation in yield, ranging from 20 % to 60 % (Al-Obaidi, 2022; Mahmood et al., 2021). This disparity may be attributed to several factors, including the homogeneity of the cultivars in the present study, obtained under a unified breeding scheme, the uniform application of an effective fertilizer across all cultivars, and the nutrient supply in these experiments meeting the plants' requirements, which may have contributed to this observed behavior. Also, the genotypes showed considerable variations in anthocyanin and carotene concentration. This result is comparable to previous studies, which found that the proportion of total soluble solids ranged between 3.6 % and 7.3 %. Additionally, total acidity in fruit from 17 cherry tomato genotypes was also examined, with fruit acidity ranging from 0.33 % to 0.85 % (Haidar, 2022).

The foliar application of salicylic acid notably enhanced leaf chlorophyll content, fruits per plant, fruit weight, plant yield, total soluble solids and total acidity of cherry tomato plants as compared to control. Since SA regulates the biogenesis of chloroplast (Qadir et al., 2019), it has been found to ameliorate chlorophyll in tomato (Baek et al., 2021; Melo, 2022; Sarinana-Aldaco et al., 2020; Silva et al., 2022; Tokas et al., 2023) and elevate SPAD value and photosynthetic activity in plants (Silva et al., 2022). As for the performance of SA in increasing fruit number, Omar et al. (2020) evaluated that SA improves flower setting in various plants, which results in an enhanced number of fruits per plant.

The superior response to spray SA phytohormones in terms of yield and fruit quality highlights the effectiveness of these phytohormones under these conditions. Foliar application of the 200 mg/L SA promoted the chlorophyll synthesis, yield characteristics and fruit quality of tomato genotypes, which were related to the SA nutritional status of tomato genotypes. This could be attributed to the synergistic relationship between SA and MeJA, which helps raise the efficiency of photosynthesis and the accumulation of nutrients within the leaf cellular structure, enhancing the vegetative growth of tomato and their production (Melo, 2022). By altering the signaling pathways of plant hormones involved in growth, development and immunity, SA and MeJA applied topically improved plant physiological performance.

Both SA and MeJA play an important role in the regulation of a variety of physiological-metabolic activity processes, including cell division, morphogenesis, and senescence (Pascual et al., 2023; Tokas et al., 2023). Notably, foliar application of phytohormones is a common agricultural practice in vegetable cultivation that not only increases vegetable yield but also enhances plant tolerance to water deficits in arid and semi-arid areas (Davies, 1995; Sarinana-Aldaco et al., 2020). Therefore, agronomic management, including the use of phytohormones has become one of the cutting-edge research topics to improve tomato tolerance to water stress (Bader et al., 2020; Ding et al., 2021; Manan et al., 2016).

Similar results indicating that SA improves flowering (Tokas et al., 2023), ensuring more fruits per plant with greater size and weight, as the application of SA accelerates cell division in all organs (Wang et al., 2022). An increase in performance occurs when using low doses, while high doses decrease it (Zhang & Huang, 2013). The plant's response to SA is concentration-dependent, since at low doses performance is promoted and moderate doses improve fruit quality characteristics and induce resistance to stress, while higher concentrations can cause cell death (Qin et al., 2024). Even though this effect was not observed in the results, it is possible that a phytotoxicity threshold has not been reached, as being within this threshold causes stress that the plant cannot control (Salman & Sadik, 2016).

Total soluble solids content and titratable acidity are two of the most important characteristics in the processing industry (Hamdi, 2017); quality is associated with soluble sugars (flavor and sweetness), which are correlated with the degree of maturity and vitamin C (Hamdi, 2022; Sarinana-Aldaco et al., 2020). Total soluble solids are affected by the type of growth habit, where tomatoes with determinate growth tend to have a lower number of soluble solids in the fruits compared to those with indeterminate growth, as shown in the data found in this research, because the latter have a greater number of leaves in relation to the number of fruits, which generates a greater capacity of the fruits to extract photoassimilates (Özden & Kulak, 2023).

The results are consistent with those reported by Chakma et al. (2021) and Kaya et al. (2023), who informed a greater accumulation of TSS in fruits exposed to SA. The increases in TSS were due to the fact that SA improves the efficiency of the rubisco enzyme and elevates the content of chlorophyll. Therefore, the rate of photosynthesis increases, which is directly reflected in the accumulation of photoassimilates in the fruits, enhancing the TSS (Li et al., 2022). Ullah et al. (2019) observed that the constituent levels of titratable acidity in tomato fruits treated with salicylic acid concentrations were higher than those of control fruit. The rise in the total acidity of tomato fruit juice might be due to the fact that salicylic acid is a good source of certain acids like ascorbic acid, which is directly involved in raising the total acidity of tomato fruit juice (Baninaiem et al., 2016; Mohamed et al., 2017).

The results and conclusions of this study are based on data from one year and one environment. To enhance reliability and accuracy, repeated work over multiple years and in various environments will be the focus of the next steps.

Conclusions

The cherry tomato genotypes displayed a positive response to the application of the phytohormones methyl jasmonate and salicylic acid. The IQ2 genotype responded better to the 200 mg/L methyl jasmonate treatment due to its superior performance in fruit weight, plant yield, productivity and titratable acidity compared to the other factors, indicating that the genotypes behave differently. According to the main factor (phytohormones), the highest yield and fruit quality were achieved with a 200 mg/L dose of salicylic acid. Further validation at a larger scale in real production settings is highly recommended.

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