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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 have insufficient 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. Salicylic acid (SA) and methyl jasmonate (MeJA) phytohormones 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 cvs. colorful tomato under greenhouse conditions. **Materials and methods.** The trial was carried out in the University of Diyala, Iraq, from 1 December, 2022 to 5 June 2023. Foliar of 0, 200 mg/L SA and or 200 mg/L MeJA was evaluated to determine effects on fruit quality and production of colorful cherry tomato cultivars indeterminate: LA4013, LA353, LA2921, LA3899 and IQ2, with a randomized complete block design with each treatment having three replicates. **Results.** The cv. IQ2 had the heaviest fruit (82.13 g), highest yield (4.56 kg/plant), total yield (4.56 t/house) and highest treatable acidity (0.62 %). The cv. LA4013 had a higher fruit number (612.88 fruit/plant) and the highest total soluble solids (2.933 %). Foliar of SA at 200 mg/L had the highest chlorophyll index (36.68 SPAD) highest fruits per plant (373.73), highest yield (3.15 kg/plant) and total yield (3.93 t/house). **Conclusion.** When considering all variables together, the best genotypes were IQ2 and LA4013, which were found to be superior to the other genotypes in quality and yield trials. The 200 mg/L foliar SA improved the 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 medio ambiente, la salud humana y la seguridad alimentaria. Los reguladores de crecimiento naturales derivados de plantas son respetuosos con el medio ambiente y tienen un precio razonable. Los ácidos salicílicos (SA) y la fitohormona jasmonato de metilo (MeJA), son cruciales para mejorar la biomasa vegetal, la calidad, la productividad y la resistencia tensiones ambientales. **Objetivo.** Evaluar el foliar efecto deMeJA y SA sobre la calidad y producción de frutos de cvs. tomate en condiciones de invernadero. **Materiales y métodos.** La prueba se llevó a cabo ende la Universidad de Diyala, Irak, del 1 de diciembre de 2022 al 5 de junio de 2023. Se evaluó la foliar de 0, 200 mg/L de SA o 200 mg/L de MeJA para determinar los efectos sobre calidad de fruto y producción cultivares de tomate cherry de crecimiento vegetativo indeterminado: LA4013, LA353, LA2921, LA3899 e IQ2, con un diseño de bloques completos al azar teniendo cada tratamiento tres repeticiones. **Resultados.** El CV. IQ2 tuvo la fruta más pesada (82,13 g), mayor rendimiento (4,56 kg/planta),rendimiento total (4,56 t/casa) y la mayor acidez tratable (0,62 %). El CV. LA4013 tuvo mayor número de frutos (612,88 frutos/planta) y mayor sólidos solubles totales (2,933 %). La foliar de SA a 200 mg/L tuvo el índice de clorofila más alto (36,68 SPAD), mayor número de frutos por planta (373,73), mayor rendimiento (3,15 kg/planta) y rendimiento total (3,93 t/casa). **Conclusión.** Al considerar todas las variables en conjunto, los mejores genotipos fueron IQ2 y LA4013, que resultaron superiores a los otros genotipos en los ensayos de calidad y rendimiento.El SA foliar de 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 tomato such as its color, shape, and size as well as its durability and shelf life are the key determinants of its 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, 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 aquaporin, including plasma membrane intrinsic proteins, are all 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 bio stimulants may interact with one another in a number of ways, including by modifying one another's production and affecting signalling pathways in plant physiology (Altaf et al., 2022; Khalloufi et al., 2017). According to one theory, the interplay of bio stimulants influences plant physiology in a synergistic manner and plays a key role in regulating plant growth and development through the control of physiological and biochemical traits and 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 that is created by a series of enzymes found in the plastid, peroxisomes, and the cytoplasm's octadecanoid

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acid (Environmental Protection Agency, 2013). JAs are oxylipin-type plant hormones that were first identified as a signal associated with wounds and that control a number of 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; anthocyanin biosynthesis; and photosynthetic carbon fixation (Qin et al., 2024). JAs also protects 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 et al., 2023**). The use of JAs to enhance growth mechanisms *diferenciar* in tomatoes is still novel and needs more research since 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 that has been well demonstrated to contribute to both local and systemic plant defence 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 effect of foliar application of phytohormones MeJA and SA on fruit quality and production of cvs. colorful tomato 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 1 December to 5 June, 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; EC, 0.7 dS; CaCO3, 6 %; organic matter, 1.50 %; available N, P and K were 30.80, 6.90 and 23 mg/kg respectively. The soil content elements were measured according to (Ostrowska et al., 1991) and were the soil samples taken before cultivation at a depth of 0.3 m.

The plant materials; 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 genotypes indeterminate have the potential for high yielding and their 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 3-4 leaf stages, uniformly vigorous seedlings were transplanted to the field on 1 December, 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, sources were K_2SO_4 at 150 kg/ha. Each plot is 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 laid out in a randomized complete block design by two factors (5 cultivars into the first factor and 3 doses; 0 mg/L, 200 mg/L SA, or 200 mg/L MeJA as a foliar spray) with three replicates. MeJA and AS were obtained from Duchefa Biochemie, Haarlem, Netherlands. To avoid rapid drying of solutions, all applications were made in the early morning using a manual pressure sprayer, covering the plant leaves until they ran off.

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The plants were taught vertically, and trailing, lateral stem, and basal leaf trimming procedures were performed on a regular basis. The irrigation was done using a drip irrigation system with pressure-compensated 4 L/h emitters and was supplied to maintain excess drainage not higher than 20 %. Field capacity irrigation was applied to all treatments. Using chromo tropic traps to keep an eye on the main pests also helped to accomplish integrated management of them.

Fruit harvest began on 20 April and ended on 5 June as they reached ripeness. Data were collected from 5 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. TSS was determined using a hand reflectometer (Brixstix BX 100 Hs; Technique Corporation, Livermore, CA). Treatable 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 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 yield plant and total yield (Table 1).

The genotype-affected values for all measured traits varied (Table 2). The 'LA353' had the highest relative chlorophyll content (51.32 SPAD). The 'LA4013' produced the highest number of fruit and TSS, which were 612.88 fruit/plant and 2.93 % respectively. The '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 'LA292' and 'IQ2' were the best, with values of 0.59 and 0.62 % respectively. compared with other genotypes.

Spray application of phytohormones has an effect on all measured traits (Table 3). Plants treated with 200 mg/L SA had 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), 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 treatable acidity was produced with both treatments (0 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 cv. 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) were produced on 'LA4013' with use of MeJA at 200 mg/L. The cv. 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 treatable acidity (0.66 %). The cv. LA4013 treated with 200 mg/L SA produced the highest total soluble solids (3.10 %) compared with other treatments.

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 treatable 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 1 December, 2022, to 5 June 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 de fruto, rendimiento, rendimiento total, sólidos solubles totales y características de acidez tratable 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. fruit per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	[a]TSS (%)	[b]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%.
[a]TSS= total soluble solids. [b]TA= treatable acidity. / [a]TSS= sólidos solubles totales. [b]TA= acidez tratable.

Table 2. Effect of genotypes on chlorophyll index, number and weight of fruit, yield, total yield, total soluble solids and treatable 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 1 December, 2022 to 5 June 2023.

Cuadro 2. Efecto de los genotipos sobre el índice de clorofila, número y peso de frutos, rendimiento, rendimiento total, sólidos solubles totales y rasgos de acidez tratables 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. Fruit per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	[b]TSS (%)	[c]TA (%)
LA4013	34.08c[a]	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

[a]Values in columns followed by the same letter are not significantly different, P<0.05, Tukey's HSD test. / [a]Los valores en las columnas seguidas de la misma letra no son significativamente diferentes, P<0,05, prueba HSD de Tukey.
[b]TSS= total soluble solids. [c]TA= treatable acidity. / [b]TSS= sólidos solubles totales. [c]TA= acidez tratable.

Table 3. Effect of spray application of phytohormones on chlorophyll index, number and weight of fruit, yield, total yield, total soluble solids and treatable 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 1 December 2022 to 5 June 2023.

Cuadro 3. Efecto de la aplicación por aspersión de fitohormonas sobre el índice de clorofila, número y peso de frutos, rendimiento, rendimiento total, sólidos solubles totales y características de acidez tratables 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.

Foliartal (200 mg/L)	Chlorophyll (SPAD)	NO. Fruit per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	[b]TSS(%)	[c]TA(%)
0	34.72c[a]	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

[a]Values in columns followed by the same letter are not significantly different, P<0.05, Tukey's HSD test. / [a]Los valores en las columnas seguidas de la misma letra no son significativamente diferentes, P<0,05, prueba HSD de Tukey.
[b]TSS= total soluble solids. [c]TA= treatable acidity. / [b]TSS= sólidos solubles totales. [c]TA= acidez tratable.

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 treatable 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 1 December 2022 to 5 June 2023.

Cuadro 4. Efecto de la interacción entre el genotipo y la aspersión de fitohormonas sobre el índice de clorofila, número y peso de frutos, rendimiento, rendimiento total, sólidos solubles totales y características de acidez tratables 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. Fruit per plant	Fruit weight (g)	Plant yield (kg/plant)	Total yield (t/house)	[b]TSS (%)	[c]TA (%)
LA4013	0	34.83^{ea}	609.66 ^{a}	4.33 ^{i}	2.63 ^{fg}	3.29 ^{gf}	2.70 ^{c}	0.52 ^{ed}
	SA	32.06^{f}	614.00 ^{a}	4.60 ^{hi}	2.67 ^{fge}	3.34 ^{gef}	3.10 ^{a}	0.44 ^{g}
	MeJA	35.36^{e}	615.00 ^{a}	4.93 ^{h}	3.02 ^{d}	3.77 ^{d}	3.00 ^{b}	0.46 ^{f}
LA353	0	47.60^{b}	324.66 ^{e}	8.63 ^{f}	2.80 ^{ef}	3.49 ^{ef}	1.20 ^{hg}	0.45 ^{f}
	SA	52.73^{a}	332.33 ^{ed}	9.13 ^{e}	3.03 ^{d}	3.78 ^{d}	1.40 ^{ghf}	0.48 ^{ef}
	MeJA	35.63^{e}	338.00 ^{d}	9.66 ^{d}	3.24 ^{c}	4.04 ^{c}	1.66 ^{ed}	0.49 ^{ef}
LA2921	0	28.30^{gh}	309.00 ^{f}	8.06 ^{g}	2.60 ^{g}	3.25 ^{g}	1.76 ^{d}	0.57 ^{cd}
	SA	27.10^{h}	312.00 ^{f}	8.26 ^{g}	2.57 ^{g}	3.21 ^{g}	1.50 ^{gdf}	0.61 ^{bc}
	MeJA	38.03^{d}	330.66 ^{ed}	8.76 ^{f}	2.83 ^{e}	3.53 ^{e}	1.60 ^{edf}	0.61 ^{bc}
LA3899	0	28.40^{g}	495.66 ^{c}	2.40 ^{k}	1.18 ^{i}	1.48 ^{i}	1.13 ^{h}	0.61 ^{bc}
	SA	25.06^{h}	521.00 ^{b}	2.63 ^{jk}	1.36 ^{h}	1.70 ^{h}	1.10 ^{i}	0.55 ^{d}
	MeJA	22.13^{i}	523.00 ^{b}	2.86 ^{j}	1.49 ^{h}	1.86 ^{h}	2.10 ^{c}	0.55 ^{d}
IQ2	0	34.46^{e}	51.33 ^{h}	80.26 ^{c}	4.17 ^{b}	5.21 ^{b}	1.50 ^{dg}	0.63 ^{ab}
	SA	44.06^{c}	52.66 ^{g}	82.46 ^{b}	4.33 ^{b}	5.32 ^{b}	2.10 ^{c}	0.56 ^{cd}
	MeJA	34.26^{e}	62.00 ^{g}	83.66 ^{a}	5.18 ^{a}	6.47 ^{a}	1.30 ^{ghf}	0.66 ^{a}

[a]Values in columns followed by the same letter are not significantly different, P<0.05, Tukey's HSD test. / [a]Los valores en las columnas seguidas de la misma letra no son significativamente diferentes, P<0,05, prueba HSD de Tukey.
[b]TSS= total soluble solids. [c]TA= treatable acidity. / [b]TSS= sólidos solubles totales. [c]TA= acidez tratable.

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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 to 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 fruit 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 tomato: fruit number per plant, fruit weight and plant yield obtained values recorded 512.32, 8.41 g and 2.72 kg respectively.

The observed increase 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 et al., 2023**). These results were lower than those observed in this study. These results agree with Al-Shammari & Hamdi (2021), who reported a yield of 3.94 kg/plant in tomato lines of indeterminate growth. These results 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 program.

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, that uniform application of an effective fertilizer across all cultivars, the nutrient supply in these experiments meeting the plants' requirements of the plants which might contribute to this observed behavior. Also, the genotypes showed considerable variations in anthocyanin and carotene concentration, this result is comparable to what previous studies have shown, meaning they found that the proportion of total soluble solids ranged between 3.6 and 7.3 %. Additionally, total acidity in fruit of 17 cherry tomato genotypes was also examined and fruit acidity ranged from 0.33 to 0.85 % (Haidar, 2022).

The foliar application of salicylic acid notably enhanced leaf chlorophyll content, fruit 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), therefore 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 increases 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 result in enhanced number of fruits on plant.

The superior response to spray SA phytohormones in terms of yield and fruit quality counts highlights the effectiveness of this 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 agriculture 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 AS improves flowering (Tokas et al., 2023), hence ensuring more fruits per plant and of greater size and weight, since the application of AS accelerates the cell division of all organs in general (Wang et al., 2022). An increase in performance 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, since being within this threshold causes stress that the plant cannot control (Salman & Sadik, 2016).

Total soluble solids content and treatable 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 was due to the fact that SA improves the efficiency of the rubisco enzyme and increases the content of chlorophyll, therefore, the rate of photosynthesis increases and this is directly reflected in the accumulation of photo-assimilates in the fruits, increasing the TSS (Li et al., 2022). Ullah et al. (2019) observed that constituent levels of titratable acidity of tomato fruits treated with salicylic acid concentrations were higher than those of control fruit. The increased 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 the rising of 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 phytohormones 'methyl jasmonate and salicylic acid'. A 200 mg/L aqueous solution was applied through leaf spraying.. The IQ2 genotype had a better response to the application of a 200 mg/L methyl jasmonate dose of phytohormone due to its better response to fruit weight, plant yield, productivity and treatable acidity compared to the other factors, showing that the genotypes behave differently. According to the main factor only (phytohormones), the highest yield and fruit quality occurred at a 200 mg/L dose of salicylic acid compared to the other treatments. Further validation at a larger scale in actual production setting is highly recommended.

References

Abood, M. A., Al-Shammari, A. M. A., & Hamdi, G. J. (2019). Foliar application of tecamin max® to alleviate water deficit effects on yield and water-use efficiency (WUE) of okra. *Acta Scientiarum Polonorum Hortorum Cultus*, *18*(2), 15–20. https://doi.org/10.24326/asphc.2019.2.2

Ali, M., & Ohri, P. (2023). Deciphering the synergistic effect of Jasmonic acid and Spermine in mitigating root-knot nematode stress in tomato plants through enhancing growth and activity of antioxidant enzymes. *South African Journal of Botany, 161*, 21-35. https://doi.org/10.1016/j.sajb.2023.07.063

Al-Mfargy, O. K. A., & Al-Juwari, M. S. M. (2023). Estimation of hybrid vigor for flowering and yield cherry tomato hybrids. *IOP Conference Series*,*1158*(4), Article 042066. https://doi.org/10.1088/1755-1315/1158/4/042066

Al-Obaidi, A. R. H. H. (2022). *Genetic analysis of individual hybrids the development and evaluation of triple hybrids for the tomato crop dissertation submitted* [Doctoral dissertation, University of Diyala]. RGnowledge. https://doi.org/10.13140/RG.2.2.11768.52484

Al-Shammari, A. M. A., & Hamdi, G. J. (2021). Genetic diversity analysis and DNA fingerprinting of tomato breeding lines using SSR markers. *Agraarteadus, 32*(1), 1-7. https://doi.org/10.15159/jas.21.13

Al-Shammari, A. M. A., & Hamdi, G. J. (2022). Effect of water deficit on the growth and yield of different genotypes of tomato in semi-arid climate conditions. *Agraarteadus, 33*(2), 389–395. https://doi.org/10.15159/jas.22.29

Al-Shammari, A. M. A., & Hamdi, G. J. (2023). Genotype and foliar fertilization affect growth, production and accumulation of anthocyanin in red cabbage. *International Journal of Vegetable Science, 29*(4), 337–347. https://doi.org/10.1080/19315260.2023.2219672

AL-Surhanee, A. A. (2022). Protective role of antifusarial eco-friendly agents (Trichoderma and salicylic acid) to improve resistance performance of tomato plants. *Saudi Journal of Biological Sciences, 29*(4), 2933-2941. https://doi.org/10.1016/j.sjbs.2022.01.020

Altaf, M. A., Shahid, R., Ren, M.-X., Naz, S., Altaf, M. M., Khan, L. U., Tiwari, R. K., Lal, M. K., Shahid, M. A., Kumar, R., Nawaz, M. A., Jahan, M. S., Jan, B. L., & Ahmad, P. (2022). Melatonin improves drought stress tolerance of tomato by modulating plant growth, root architecture, photosynthesis, and antioxidant defense system. *Antioxidants, 11*(2), Article 309. https://doi.org/10.3390/antiox11020309

Alwan, O. K., & Mohammed, M. S. (2023). Study of combining ability analysis in cherry tomato (*Solanum lycopersicum* var. *cerasiforme*). *Diyala Agricultural Sciences Journal, 15*(1), 49-55. https://doi.org/10.52951/dasj.23150106

Alwan, O. K., Al-Zuhairy, N. S. A., & Badri, A. N. (2023). Estimation of some genetic parameters and field evaluation for pure lines of cherry tomato. *IOP Conference Series, 1252*(1), Article 012096. https://doi.org/10.1088/1755-1315/1252/1/012096

Alwan, O. K., Hamdi, G. J., & Maleh, R. A. (2023). Methyl jasmonate and type of fertilization affect growth, production and accumulation of sulforaphane in black radish taproot. *International Journal of Vegetable Science, 29*(2), 178-194. https://doi.org/10.1080/19315260.2023.2170302

Arshad, A., Mushtaq, N., Sajjad, M., Ahad, A., Ilyas, M., & Gul, A. (2023). Role of exogenous phytohormones in mitigating stress in plants. In M. Ozturk, R. A. Bhat, M. Ashraf, F. M. P. Tonelli, B. T. Unal, & G. H. Dar (Eds.), *Phytohormones and Stress Responsive Secondary Metabolites* (pp. 111–131). Elsevier, Islamabad. https://doi.org/10.1016/B978-0-323-91883-1.00020-6

Bader, B. R., Abood, M. A., Aldulaimy, S. E. H., Al-Mehmdya, S. M. H., & Hamdi, G. J. (2020). Effect of water deficit and foliar application of amino acids on growth and yield of eggplant irrigated by two drip systems under greenhouse conditions. *Agraarteadus, 31*(2),131–138. https://doi.org/10.15159/jas.20.20

Baek, M. W., Choi, H. R., Yun Jae, L., Kang, H. M., Lee, O. H., Jeong, C. S., & Tilahun, S. (2021). Preharvest treatment of methyl jasmonate and salicylic acid increase the yield, antioxidant activity and GABA content of tomato. *Agronomy, 11*(11), Article 2293. https://doi.org/10.3390/agronomy11112293

Baninaiem, E., Mirzaaliandastjerdi, A. M., Rastegar, S., & Abbaszade, K. H. (2016). Effect of pre-and postharvest salicylic acid treatment on quality characteristics of tomato during cold storage. *Advances in horticultural science, 30*(3), 183-192. http://dx.doi.org/10.13128/ahs-20281

Borysiuk, K., Ostaszewska-Bugajska, M., Kryzheuskaya, K. Gardeström, P., & Bożena Szal, B. (2022). Glyoxalase I activity affects Arabidopsis sensitivity to ammonium nutrition. *Plant Cell Reports, 41*(12), 2393–2413. https://doi.org/10.1007/s00299-022-02931-5

Chakma, R., Biswas, A., Saekong, P., Ullah, H., & Datta, A. (2021). Foliar application and seed priming of salicylic acid affect growth, fruit yield, and quality of grape tomato under drought stress. *Scientia Horticulturae, 280,* Article 109904. https://doi.org/10.1016/j.scienta.2021.109904

Chen, R. Y., Jiang, W., Fu, S. F., & Chou, J. Y. (2022). Screening, evaluation, and selection of yeasts with high ammonia production ability under nitrogen free condition from the cherry tomato (*Lycopersicon esculentum* var. *cerasiforme*) rhizosphere as a potential bio-fertilizer. *Rhizosphere, 23,* Article 100580. https://doi.org/10.1016/j.rhisph.2022.100580

Davies, P. J. (1995). The plant hormones: their nature, occurrence, and functions. In P. J. Davies (Ed.), *Plant hormones: physiology, biochemistry & molecular biology* (pp. 1-12). Springer Dordrecht. https://doi.org/10.1007/978-94-011-0473-9_1

Ding, F., Wang, C., Xu, N., Wang, M., & Zhang, S. (2021). Jasmonic acid-regulated putrescine biosynthesis attenuates cold-induced oxidative stress in tomato plants. *Scientia Horticulturae, 288,* Article 110373. https://doi.org/10.1016/j.scienta.2021.110373

Environmental Protection Agency. (2013). *Methyl Jasmonate; Exemption from the requirement of a tolerance*. *Federal Register, 78,* 22789-22794.

Fan, S., Wu, H., Gong, H., & Guo, J. (2022). The salicylic acid mediates selenium-induced tolerance to drought stress in tomato plants. *Scientia Horticulturae, 300*, Article 111092. https://doi.org/10.1016/j.scienta.2022.111092

Farooq, M., Wahid, A., Kobayashi, N. S. M. A., Fujita, D. B. S. M. A., & Basra, S. M. A. (2009). Plant drought stress: effects, mechanisms and management. *Agronomy for Sustainable Development, 29*,153–188. https://doi.org/10.1051/agro:2008021

con tildes Garcia-Caparros, P., De Filippis, L., Gul, A., Hasanuzzaman, M., Ozturk, M., Altay, V., & Lao, M. T. (2021). Oxidative stress and antioxidant metabolism under adverse environmental conditions: a review. *The Botanical Review, 87*, 421-466. https://doi.org/10.1007/s12229-020-09231-1

Gerszberg, A. & Hnatuszko-Konka, K. (2017). Tomato tolerance to abiotic stress: a review of most often engineered target sequences. *Plant Growth Regulation*, *83*(2), 175–198. https://doi.org/10.1007/s10725-017-0251-x

Godoy, A. J. V., Grisales, S. O., Cabrera, F. A. V., Villareal, M. D. C. S., Guzmán, D. G. G., & Villareal, F. A. S. (2022). Agronomic evaluation of chonto tomato (*Solanum lycopersicum* Mill.) lines of determinate growth. *Agronomía Colombiana, 40*(3), 336-343. https://doi.org/10.15446/agron.colomb.v40n3.103518

Haidar, A. (2022). Evaluation of various tomato cultivars for some physiochemical characteristics influencing flavor and nutritive properties. *ProEnvironment Promediu, 15*(50), 264 – 277.

Hamdi, G. J. (2017). *Effect of perlite in reducing water stress for three genotypes of tomato*. [Master's thesis, University of Diyala]. RGnowledge. https://doi.org/10.13140/RG.2.2.17884.64648

Hamdi, G. J. (2022). *Estimate the genetic distance and genetic parameters of growth characteristics and yield of tomato using half diallel cross under water stress*. [Doctoral dissertation, University of Diyala]. RGnowledge. https://doi.org/10.13140/RG.2.2.15131.75049

Kaya, C., Ugurlar, F., Ashraf, M., Alyemeni, M. N., & Ahmad, P. (2023). Exploring the synergistic effects of melatonin and salicylic acid in enhancing drought stress tolerance in tomato plants through fine-tuning oxidative-nitrosative processes and methylglyoxal metabolism. *Scientia Horticulturae, 321,* Article 112368. https://doi.org/10.1016/j.scienta.2023.112368

Khalloufi, M., Martínez-Andújar, C., Lachaâl, M., Karray-Bouraoui, N., Pérez-Alfocea, F., & Alfonso-Albacete, A. (2017). The interaction between foliar GA3 application and arbuscular mycorrhizal fungi inoculation improves growth in salinized tomato (*Solanum lycopersicum* L.) plants by modifying the hormonal balance. *Journal of Plant Physiology, 214*, 134-144. https://doi.org/10.1016/j.jplph.2017.04.012

Li, S., Huan, C., Liu, Y., Zheng, X., & Bi, Y. (2022). Melatonin induces improved protection against Botrytis cinerea in cherry tomato fruit by activating salicylic acid signaling pathway. *Scientia Horticulturae, 304,* Article 111299. https://doi.org/10.1016/j.scienta.2022.111299

Mahmood, A. K., Sulaiman, S. M., & Arkwazee, H. A. H. (2021). Evaluation of yield and fruit quality of newly introduced cherry tomato cultivars under high tunnel conditions. *Euphrates Journal of Agriculture Science, 13*(4), 35-45.

Manan, A., Ayyub, C. M., Pervez, A., & Ahmad, R. (2016). Methyl jasmonate brings about resistance against salinity stressed tomato plants by altering biochemical and physiological processes. *Pakistan Journal of Agricultural Sciences, 53*(1), 35-41. https://doi.org/10.21162/PAKJAS/16.4441

Melo, M. F. (2022). *Effect of salicylic and jasmonic acid on cherry tomato growth, physiology, and fruit quality under saline stress*. [Unpublished doctoral dissertation]. Universidade Federal Rural do Semi-Árido.

Mohamed, R. A., Abdelbaset, A. K., & Abd-Elkader, D. Y. (2017). Salicylic acid effects on growth, yield, and fruit quality of strawberry cultivars. *Journal of Medicinally Active Plants, 6*(2), 1-11.

Omar, D. G., AL-Mafargy, O. K., & Mohammed, H. A. (2020). Effect of spraying salicylic acid and zinc element on cherry tomato Solanum lycopericum L. characteristics under greenhouse conditions. *Syrian Journal of Agricultural Research, 7*(4), 1-12.

Ostrowska, A., Gawliński, S., & Szczubiałka, Z. (1991). *Methods of analysis and assessment of soil and plant properties. A Catalgoue*. Institute of Environmental Protection–National Research Institute.

Özden, E., & Kulak, M. (2023). Salicylic acid biosynthesis for hormone crosstalk and plant development. In A. Husen, & W. Zhang (Eds.), *Hormonal cross-talk, plant defense and development* (pp. 61–74). Elsevier, Igdir. https://doi.org/10.1016/B978-0-323-95375-7.00006-9

Ozturk, M., & Unal, B. T. (Eds.). (2023). Exogenous application of phytohormones and phytometabolites to plants to alleviate the effects of drought stress. In M. Ozturk, R. A. Bhat, M. Ashraf, F. M. P. Tonelli, B. T. Unal, & G. H. Dar (Eds.), *Phytohormones and stress responsive secondary metabolites* (pp. 1–12). Elsevier, Izmir. https://doi.org/10.1016/B978-0-323-91883-1.00001-2

Pascual, L. S., Mittler, R., Sinha, R., Peláez-Vico, M. A., López-Climent, M. F., Vives-Peris, V., Gómez-Cadenas, A., & Zandalinas, S. I. (2023). Jasmonic acid is required for tomato acclimation to multifactorial stress combination. *Environmental and Experimental Botany, 213,* Article 105425. https://doi.org/10.1016/j.envexpbot.2023.105425

Qadir, A., Anjum, M. A., Nawaz, A., Ejaz, S., Altaf, M. A., Shahid, R., & Hassan, A. (2019). Growth of cherry tomato in response to salicylic acid and glycinebetaine under water stress condition. *Middle East Journal of Agriculture Research, 8*(3), 762-775.

Qin, C., Lian, H., Alqahtani, F. M., & Ahanger, M. A. (2024). Chromium mediated damaging effects on growth, nitrogen metabolism and chlorophyll synthesis in tomato can be alleviated by foliar application of melatonin and jasmonic acid priming. *Scientia Horticulturae, 323,* Article 112494. https://doi.org/10.1016/j.scienta.2023.112494

Ranganna, S. (1977). *Manual of analysis fruits and vegetables*. Tata-McGraw Hill.

Raza, A., Charagh, S., Najafi-Kakavand, S., Abbas, S., Shoaib, Y., Anwar, S., Sharifi, S., Lu, G., & Siddique, K. H. (2023). Role of phytohormones in regulating cold stress tolerance: physiological and molecular approaches for developing cold-smart crop plants. *Plant Stress, 8*, Articles 100152. https://doi.org/10.1016/j.stress.2023.100152

Salman, A. D. & Sadik, S. (2016). Influerce of foliar application of agrosol and enraizal on the qualitative characters of the fruits of cherry tomato grown under open field and plastic house conditions. *Iraqi Journal of Agricultural Sciences, 47*(2), 495-505. https://doi.org/10.36103/ijas.v47i2.594

Sarinana-Aldaco, O., Sanchez-Chavez, E., Fortis-Hernandez, M., GonzáLez-Fuentes, J. A., Moreno-Resendez, A., Rojas-Duarte, A., & Preciado-Rangel, P. (2020). Improvement of the nutraceutical quality and yield of tomato by application of salicylic acid. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca, 48*(2), 882-892. https://doi.org/10.15835/nbha48211914

Silva, A. A. R., Lima, G. S., Azevedo, C. A. V., Veloso, L. L. S. A., Lacerda, C. N., Gheyi, H. R., Pereira, W. E., Silva, V. R., & Soares, L. A. A. (2022). Methods of application of salicylic acid as attenuator of salt stress in cherry tomato. *Brazilian Journal of Biology, 82,* Article e265069. https://doi.org/10.1590/1519-6984.265069

Simonne, A. H., Fuzeré, J. M., Simonne, E., Hochmuth, R. C., & Marshall, M. R. (2007). Effects of nitrogen rates on chemical composition of yellow grape tomato grown in a subtropical climate. *Journal of Plant Nutrition, 30*(6), 927-935. https://doi.org/10.1080/15226510701375465

Simonne, E., Hochmuth, R., Hochmuth, G., & Studstill, D. W. (2008). Development of a nitrogen fertigation program for grape tomato. *Journal of Plant Nutrition, 31*(12), 2145-2154. https://doi.org/10.1080/01904160802460102

Singhal, P., Jan, A.T., Azam, M., & Haq, Q. M. R. (2016). Plant abiotic stress: a prospective strategy of exploiting promoters as alternative to overcome the escalating burden. *Frontiers in Life Science, 9*, 52–63. https://doi.org/10.1080/21553769.2015.1077478

Tokas, J., Kumar, N., Punia, H., Dhankar, S. K., Yashveer, S., Singal, H. R., & Sheokand, R. N. (2023). Response of antioxidant system to postharvest salicylic acid treatment in tomato (*Solanum lycopersicum* L.) fruit stored at ambient temperature. *Journal of Agricultural Science and Technology, 25*(1), 155-169. https://doi.org/10.52547/jast.25.1.155

Tonelli, F. M. P., Tonelli, F. C. P., & Lemos, M. S. (2023). Exogenous application of phytohormones to increase plant performance under stress. In M. Ozturk, R. A. Bhat, M. Ashraf, F. M. P. Tonelli, B. T. Unal, & G. H. Dar (Eds.), *Phytohormones and Stress Responsive Secondary Metabolites* (pp. 275–285). Elsevier, Divinópolis. https://doi.org/10.1016/B978-0-323-91883-1.00004-8

Ullah, A., Ali, S., & Shah, S. M. (2019). Influence of foliar application of bio-stimulants on growth, yield and chemical composition of tomato Influence of foliar application of bio-stimulants on growth, yield and chemical composition of tomato. *International Journal of Biosciences, 14,* 309-316. http://dx.doi.org/10.12692/ijb/14.1.309-316

Wang, M., Zhang, S., & Ding, F. (2020). Melatonin mitigates chilling-induced oxidative stress and photosynthesis inhibition in tomato plants. *Antioxidants, 9*(3), Article 218. https://doi.org/10.3390/antiox9030218

Wang, P., Sun, S., Liu, K., Peng, R., Li, N., Hu, B., Wang, L., Wang, H., Afzal, A. J., & Geng, X. (2022). Physiological and transcriptomic analyses revealed gene networks involved in heightened resistance against tomato yellow leaf curl virus infection in salicylic acid and jasmonic acid treated tomato plants. *Frontiers in Microbiology, 13,* Article 970139. https://doi.org/10.3389/fmicb.2022.970139

Yu, G. B., Chen, R. N., Chen, Q. S., Chen, F. Q., Liu, H. L., Ren, C. Y., Zhang, Y. X., Yang, F. J., & Wei, J. P. (2022). Jasmonic acid promotes glutathione assisted degradation of chlorothalonil during tomato growth. *Ecotoxicology and Environmental Safety, 233*, Article 113296. https://doi.org/10.1016/j.ecoenv.2022.113296

Zhang, C., & Huang, Z., (2013). Effects of endogenous abscisic acid, jasmonic acid, polyamines, and polyamine oxidase activity in tomato seedlings under drought stress. *Scientia Horticulturae, 159*, 172-177. https://doi.org/10.1016/j.scienta.2013.05.013

Zhu, J. K. (2016). Abiotic stress signaling and responses in plants. *Cell, 167*(2), 313-324. https://doi.org/10.1016/j.cell.2016.08.029