Assiut Journal of Agricultural Sciences 56 (1) 2025 (296-313)
ISSN: 1110-0486 / EISSN: 2356-9840
Website: http://ajas.journals.ekb.eg/
E-mail: ajas@aun.edu.eg

(Original Article)

Preharvest Spraying of Calcium Chloride, Chitosan, and their Combination Effects on Tomato Growth, Yield, Fruit Characteristics, and Quality

Hasnaa M. Abdelaleem; Mohamed H.Z. EL-Dkeshy and Reham M. Abdalla*

Vegetable Crops Department, Faculty of Agriculture, Assiut University Assiut, Egypt.

Corresponding author e-mail: reham.abdalla@aun.edu.eg
DOI: 10.21608/AJAS.2025.330403.1417

Abstract

Postharvest losses are a great obstacle that reduces tomato production in many developing countries, including Egypt. Research was carried out to evaluate the effects of pre-harvest treatments on growth, fruit yield, quality, and fruit characteristics of tomato; variety 'Nora 765'. The experiment comprised four spraying treatments, *viz.*, control (without spraying), calcium chloride ($CaCl_2$ 1.5%), chitosan 1.5%, and a combination of chitosan 1.5% + $CaCl_2$ 1.5%, sprayed either foliar (F) or at Green Mature Fruits stage (GM). Foliar spraying with $CaCl_2$ gave the tallest plants and the widest stems. Also, $CaCl_2$ treated plants sprayed at either F or GM had higher fruit numbers than most of the treatments. Spraying the foliage with $CaCl_2$ gave significantly the highest fruit yield in the experiments and showed a lower fruit weight loss than the control in most of the days. In the first season only, plants' foliar sprayed with $CaCl_2$, chitosan, and mix treatments had better visual appearance and hardness than control fruits after 12 days of storage. Foliar spraying with chitosan had lower microbial fungi than the control. Flavonoids, and total phenolic contents were higher in all GM spraying treatments than the control. However, lycopene was lower in all foliar sprayed treatments than the control. It could be concluded that, under these experimental conditions, $CaCl_2$ was the best treatment for tomato growth and yield and for improving fruit visual appearance, firmness, and delaying skin color development, while foliar chitosan can be used for better postharvest fruit characteristics only.

Keywords: *Firmness, Fruit visual appearance, Fruit weight loss, Lycopene, Microbial infection*

Introduction

In the era of agricultural production, it is essential to have a steady growth in the quantities of agricultural crops and a decrease in food loss. Thus, enhancing plant growth and yield while reducing post-harvest losses would help increase the amount of food available for human consumption, required for better global food security. Postharvest losses of horticultural produce are caused by the rapid deterioration in vegetables during handling, transport, and storage (Naveena and Immanuel, 2019). Pre-harvest management can affect physico-chemical quality of fruits (Tagele *et al.*, 2022). Synthetic chemicals such as prochloraz and bavistin have been effectively

Received: 23 October 2024/ Accepted: 23 December 2024/ Published online: 23 January 2025

used to maintain the quality of fresh produce of vegetables (Shimshoni *et al.*, 2020). However, in the light of sustainable agriculture, it is very important to get rid of conventional agricultural practices and to start using biodegradable and safe products to prolong the shelf-life of vegetables and to control post-harvest decay (Chowdhury *et al.,* 2023).

Chitosan has been broadly used as a coating agent of different fruits and vegetables to protect from post-harvest losses, and to prolong storage and preservation duration (Li *et al.,* 2021; Tagele *et al.*, 2022). Chitosan is an ideal plant growth promoter resource for sustainable agriculture. Its natural and degraded forms are environmental friendly to humans, biocompatible, non-toxic and biodegradable (Chakraborty *et al.*, 2020; Mukhtar Ahmed *et al.,* 2020). Foliar application of chitosan enhances plant growth, yield, photosynthesis, generates primary and secondary metabolite responses, and exhibits antibacterial and antifungal activities (Mukhtar Ahmed *et al.*, 2020).

Calcium is an essential plant element as it plays vital roles in plant growth and development. It has several structural roles in the cell walls and membranes of plants (White and Broadley, 2003). It is important for the cell at the apical growth of shoot/root, for early root formation and growth, and seed and grain production. The application of calcium reduces the incidence of blossom end rot in fruits, the observation of tip burn and brown heart in leafy vegetables (Sajid *et al.*, 2020). Calcium also has a main role in maintaining fruit quality, firmness, and fruit shelf life (Ramezanian *et al.,* 2018). Calcium chloride decreases postharvest weight losses and increases shelf life of vegetables (Naveena and Immanuel, 2019).

Tomato (*Solanum lycopersicum* L.) is one of the most popular vegetable crops and the third most important crop worldwide (FAOSTAT, 2023), due to its vast area of cultivation, and high production and consumption (Shao *et al.*, 2022). It is high in vitamin C concentrations, thus known as the "Poor Man's Orange" (Chhetri and Ghimire, 2023). Textural softening caused by ripening has negative consequences on storage. The fruit is climacteric, perishable in nature, and has high ethylene production after harvest, which makes it the postharvest shelf-life poorest vegetable (Chhetri and Ghimire, 2023). Therefore, this study aimed at examining the influence of preharvest sprays (whether spraying on foliage or green mature fruits) with chitosan, calcium chloride, and their combination on the growth, fruit yield, and postharvest physico-chemical quality of tomatoes.

Materials and Methods

Tomato production and growth conditions

Two-field experiments were conducted consecutively during the fall-winter seasons from October to April of 2020\2021 (SI) and 2021\2022 (SII) at the Research Farm of the Faculty of Agriculture, Assiut University, Assiut governorate, Egypt. Seedlings of a tomato hybrid cv. “Nora 765” were used. Uniform seedling transplants were manually transplanted into individual clay soil plots (3.1 m Long × 5.6 m Wide) that have at 40-cm distance between transplants on the 8th and 11th of October of each

year. Plots were kept free from weeds manually and all cultural practices were conducted as per the recommendation for tomato production.

Treatments and preparation of treatment solutions

The field experiment comprised two factors: factor A (pre-harvest treatments) and factor B (plant organs that are sprayed). Factor A contains four spraying treatments, (without spraying), calcium chloride ($CaCl_2$) 1.5%, chitosan 1.5%, and a combination of chitosan 1.5% + $CaCl_2$ 1.5%. Factor B comprises two different spraying targets i.e., Foliar spraying (F) which was performed during the vegetative stage while the second spraying target was green mature fruits (GM). Treatments were laid out in a strip plot design with three replications.

In F treated plants, foliar spraying on plants was carried out 50 days after transplanting and spraying was repeated one month later. The canopy of tomato plants was sprayed with an aqueous solution to run-off from top to bottom of the plants to include all the growing plants. In the GM group, applications began at the early green mature stage. Fruits were sprayed with the above-mentioned spraying treatments without reaching the rest of the plant organs by covering the other plant parts while spraying. The spraying was repeated one month later. All products were sprayed with the use of a backpack sprayer.

The spraying solutions used in this experiment were prepared in the laboratory. Chitosan concentration of 1.5% (prepared by dissolving 15g of chitosan powder in a liter of distilled water. Ten ml of glacial acetic acid, and 0.5 ml of Tween80 was added to the chitosan solution), Calcium chloride concentration of 1.5% was prepared by dissolving 15g of calcium chloride in a liter of distilled water, and 0.5 ml of Tween80 was added to it). The mix treatment included chitosan 1.5% + $CaCl_2$ 1.5%.

Plant growth, fruit number, and fruit yield measurements

Three plants were randomly taken from each plot in each treatment to measure different growth parameters (n=9). Plant height (cm) was measured as the distance from the soil surface to the highest tip of the plants using a measuring tape. The stem diameter (cm) was measured with a Vernier caliper. The number of branches was counted per plant.

Manual harvesting of tomato fruits started in the first week of February and continued until the last week of March in the two seasons. From each experimental plot, fruit number was counted, and total fruit yield (Kg/m^2) was weighed, then total fruit yield in ton/feddan was calculated. Representative fruits sample from each plot in each treatment were sent from the farm to the laboratory at the Department of Vegetable Crops, Faculty of Agriculture, Assiut University, Assiut, Egypt, for fruit storage evaluation.

Laboratory storage evaluation

Fruits free from any defects, damages, punctures, diseases, uniform in size and weight were selected for the storage experiments in the laboratory. All fruits were washed with tap water, dried using paper tissues, numbered and kept at room temperature (ambient environment storage). All measured parameters were recorded

at time intervals of 0, 3, 6, 9, and 12 days after moving the fruits to the lab for storage experiment evaluation. The following measurements were taken on 12 fruits in each replicate:

1-Fruit weight loss (%)

The initial weight of tomato fruits was recorded just before storage. To assess the physiological loss in weight, further weight of fruits was recorded at 0, 3, 6, 9, and 12 days of storage and subtracted from the initial weight to calculate the loss in weight. It was determined with the following formula and expressed in percentage according to Moneruzzaman *et al.* (2008).

Weight loss (%) = Initial weight- Final weight/ Initial weight X 100

2-Visual appearance, hardness, shrinkage, and fungal growth

Visual appearance was evaluated based on a scale from 1 to 5 that indicates the state of its acceptable marketing appearance. The scale of appearance are, 5 = very good for marketing, 4= good, 3= fairly good or average degree; 2= its marketability is unacceptable, and 1= not suitable for marketing with speedy need of disposal. Visual appearance was recorded for shrinking, color change, decay, wilting, and or any visible deterioration as described by Ali *et al.* (2021). Fruit shrinkage was evaluated based on a scale from 1 to 5 that indicates the state in which it is accepted in terms of size of wrinkles on the peel, which in turn indicates the deterioration of the fruit, where 5 = no wrinkles, 4= the beginning of the appearance of wrinkles but is still good, 3= an increase in wrinkles but it is moderately wrinkled, 2= 75% wrinkles, and 1= severely wrinkled and not acceptable anymore. Fungal Growth was evaluated by giving the fruit a number or value based on the appearance and severity of the fungal infection on it, where 5= absence of fungal infections, 4= the beginning of the appearance of infection, 3= an increase in infection with fungus, 2 = the infection of the fungus seducer, 1 = that it is not valid and unacceptable and that it must be disposed immediately. Hardness was evaluated based on a scale from 1 to 5 that indicates the fruit hardness, where its hardness ratio value is 5= the hardness is greater than 50%, 4= the hardness is 50%, 3= it is 25%, 2= it is greater than 10%, and 1= it has become less than 10% and is being discarded.

3-Chemical analysis

Tomato fruits with decent texture and color were picked from each treatment, and were transferred to the Central laboratories, Faculty of Agriculture, Assiut University, Assiut, Egypt.

Lycopene content determination

Determination of lycopene was done on a filtered solution by reading the absorbance using a UV visible spectrophotometer at 472 nm (JENWAY 6505 UV-VIS, UK). The following formula was used for lycopene content determination: mg of lycopene per 100 g = 3.1206 × absorbance × volume × dilution/ Weight of sample × 1000 (g) × 100 (Barbu *et al.,* 2015).

Total phenolic content

The total phenolic content of the extract was determined by the Folin–Ciocalteu method (Kaur and Kapoor, 2002). The total phenolic content was calculated from the calibration curve, and the results were expressed as mg of gallic acid equivalent per g dry weight.

Total flavonoid content

The total flavonoid content of the crude extract was determined by the aluminum chloride colorimetric method (Chang *et al.,* 2002). The total flavonoid content was calculated from a calibration curve, and the result was expressed as mg rutin equivalent per g dry weight.

Statistical Analysis

The field experiments were organized in a strip plot design with three replications for each treatment. All data were statistically analyzed using ANOVA by MSTAT-C version 2.10 software, and the means of treatments were separated by Duncan Multiple Range (Steel and Torrie 1980).

Results

Effect of different spraying treatments on tomato growth and yield

This study results presented in (Table 1) depicted that plant height, stem diameter, and number of branches were not significantly affected by the treatment of spraying different plant organs (F or GM). However, F and GM plants sprayed with $CaCl_2$ were the tallest in all treatment combinations of S1, and in F plants in S2. In S2, GM plants sprayed with mix and chitosan treatments were significantly taller than those plants sprayed with chitosan at F plants. In S1, stem diameter was the widest in F plants sprayed with $CaCl_2$ (1.83 cm), but it was only significantly higher than those sprayed with chitosan (1.45 cm) at GM plants. In S2, GM plants sprayed with $CaCl_2$ were the widest (1.88 cm), followed by mix treatments in GM plants (1.78 cm), then by $CaCl_2$ at F plants (1.74 cm).

As for the mean fruit number per plot, foliar sprayed plants of S1 had significantly the highest number with $CaCl_2$ treatment, followed by control plants. In S2, also $CaCl_2$ plants had significantly higher fruit numbers than those sprayed with chitosan or mixed treatments (Table 2). In S1, GM plants of control, $CaCl_2$, and mix treatments had comparable fruit numbers. In S2, GM plants sprayed with $CaCl_2$ had significantly higher fruit numbers than all the other spraying combination treatments (Table 2). In general, plants sprayed with chitosan whether at F or GM had the lowest fruit numbers in S1 and both chitosan and mix treatments at GM had the lowest fruit numbers in S2. Moreover, the main effect of spraying plant organs showed that F plants had significantly higher fruit numbers than GM plants (Table 2).

Table 1. Effect of foliar spraying treatments and organs of plants sprayed on tomato growth traits in the two seasons

	Treatment (A)	Plant Height (cm)		Main effect factor (A)	Branches Number		Main effect treatment (A)	Stem Diameter (cm)		Main effect factor (A)
		F	GM		F	GM		F	GM	
S1	Control	93.66^{a}	80.00^{a}	86.83^{A}	14.22^{a}	14.42^{a}	14.32^{A}	1.58^{ab}	1.52^{ab}	1.55^{A}
	$CaCl_2$	98.22^{a}	82.25^{a}	90.24^{A}	16.00^{a}	12.00^{a}	14.00^{A}	1.83^{a}	1.53^{ab}	1.68^{A}
	Chitosan	92.56^{a}	76.50^{a}	84.53^{A}	13.94^{a}	13.22^{a}	13.58^{A}	1.57^{ab}	1.45^{b}	1.63^{A}
	Mixed (Chito+$CaCl_2$)	91.11^{a}	76.67^{a}	83.89^{A}	15.00^{a}	14.44^{a}	14.58^{A}	1.75^{ab}	1.51^{ab}	1.51^{A}
	Main effect organs (B) (Factor B- stage)	93.89**	78.85**	86.37	14.79 ns	13.52 ns	14.1	1.68 ns	1.50 ns	1.59
	Treatment (A)	Plant Height (cm)		Main effect factor (A)	Branches Number		Main effect treatment (A)	Stem Diameter (cm)		Main effect factor (A)
		F	GM		F	GM		F	GM	
S2	Control	100.00^{ab}	97.50^{ab}	98.75^{A}	10.67^{ab}	10.00^{ab}	10.33^{A}	1.67^{ab}	1.72^{ab}	1.70^{A}
	$CaCl_2$	100.83^{ab}	98.89^{ab}	99.86^{A}	10.00^{ab}	10.44^{ab}	10.22^{A}	1.74^{ab}	1.88^{a}	1.81^{A}
	Chitosan	89.45^{b}	102.50^{a}	95.97^{A}	8.67^{b}	12.33^{a}	10.50^{A}	1.73^{ab}	1.72^{ab}	1.73^{A}
	Mixed (Chito+$CaCl_2$)	95.00^{ab}	105.28^{a}	100.14^{A}	11.28^{ab}	10.28^{ab}	10.78^{A}	1.51^{b}	1.78^{ab}	1.65^{A}
	Main effect organs (B)	96.32 ns	101.04 ns	98.68	10.15 ns	10.76 ns	10.45	1.66 ns	1.78 ns	1.72

Means (n = 9) within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, **=highly significant≤0.01, ns: not significant.

Table 2. Effect of foliar spraying treatments and organs of plants sprayed on tomato fruits number and yield in the two seasons

	Treatment	Number of Fruits/plot		Main effect treatment (A)	Yield (ton\Fed.)		Main effect treatment (A)
		F	GM		F	GM	
S1	Control	249.00^{b}	116.50^{d}	182.75^{AB}	30.58^{ab}	13.03^{d}	21.80^{A}
	$CaCl_2$	299.50^{a}	101.50^{de}	200.50^{A}	31.86^{a}	12.04^{d}	21.95^{A}
	Chitosan	188.33^{c}	74.00^{e}	131.17^{C}	22.58^{c}	9.04^{d}	15.32^{B}
	Mixed (Chitosan+$CaCl_2$)	213.33^{bc}	99.50^{de}	156.42^{BC}	24.81^{bc}	11.82^{d}	18.32^{AB}
	Main effect plant organs (B)	237.54**	97.88**	167.71	27.46**	11.48**	19.47
	Treatment	Number of Fruits/plot		Main effect treatment (A)	Yield (ton\Fed.)		Main effect treatment (A)
		F	GM		F	GM	
S2	Control	239.33^{a}	173.50^{b}	206.42^{A}	27.30^{ab}	18.78^{cde}	23.04^{AB}
	$CaCl_2$	248.67^{a}	221.50^{a}	235.08^{A}	28.97^{a}	23.33^{bc}	26.15^{A}
	Chitosan	170.50^{b}	145.00^{b}	157.75^{B}	18.13^{de}	16.28^{e}	17.21^{BC}
	Mixed (Chitosan+$CaCl_2$)	166.00^{b}	162.50^{b}	164.25^{B}	19.10^{cde}	21.79^{cd}	20.45^{C}
	Main effect plant organs (B)	206.13*	175.63*	190.88	23.37*	20.05*	21.71

Means (n = 9) within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, *=significant ≤0.05, **=highly significant ≤0.01.

As for the yield (ton/feddan), foliar sprayed plants always had significantly higher fruit yield than those sprayed at GM plants except for the mix treatments in S2 (Table 2). Foliar spraying with $CaCl_2$ produced significantly higher fruit yield, followed by control plants in the two seasons (Table 2). Plants of GM in S1 showed insignificant differences in the yield due to spraying treatments (Table 2). However, control plants followed by those sprayed with $CaCl_2$ had the highest yields. In GM sprayed plants of S2, all treatments (control, $CaCl_2$, and mix) had significantly higher yield than chitosan treatment but the highest yield was found in those sprayed with $CaCl_2$ (Table 2).

Effect of different spraying treatments on tomato fruit characteristics and quality

The interaction effect of the spraying treatments and spraying organs showed that there were significant differences among combinations regarding fruit weight loss, visual appearance, microbial fungi, shrinkage, and hardness (Tables 3, 4, 5, 6, and 7). Decline in fruit weight was increased by increasing storage days (Table 3). In S1, F plants sprayed with $CaCl_2$, chitosan, and mix had a fruit weight loss of 11.48%, 9.62%, and 11.29%, respectively, which was significantly lower than the control (13.92%) after 12 days of storage. In S2, only F plants sprayed with $CaCl_2$ only and chitosan only had lower weight loss than the control (13.82% and 13.95% vs. 14.72%, respectively) after 12 days of storage (Table 3). At GM plants in S2, however, all treatments had lower fruit weight loss than the control after 12 days of storage, but the lowest significant fruit loss was found in $CaCl_2$ plants (Table 3).

Regarding visual appearance, there was a decline in visual appearance of fruits with increasing storage days. In S1 at F plants, after 12 days of storage, those sprayed with $CaCl_2$, chitosan, and mix treatments had significantly better visual appearance than control fruits (Table 4). Although not significant, only mixed treatment sprayed at the GM plants showed better visual appearance than the control. In S2, no differences in visual appearance were found among treatments whether sprayed at F or GM after 12 days of storage (Table 4). As for the microbial fungi occurrence, the lowest occurrence of microbial fungi was found in foliar sprayed plants with chitosan after 12 days of storage of both seasons (Table 5). Shrinkage of fruits increased with increasing storage days. Fruits of foliar sprayed plants with chitosan had significantly lower shrinkage scores than those of the control in S1 but not in S2 after 12 days of storage (Table 6). Other than that, no significant differences were found among treatments or spraying organs (Table 6). Regarding the hardness of fruits, all spraying treatments gave significantly better fruit hardness after 12 days of storage than control fruits in F plants in S1. On the other hand, control fruits had better hardness than those sprayed with the other spraying treatments at GM plants (Table 7). In S2, no such differences among treatment combinations were found in F or GM plants (Table 7).

Table 3. Effect of spraying treatments on tomato foliage or fruits on fruit weight loss% during different storage days

	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main Effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S1	Control	1.76^{a}	0.83^{b}	1.30^{A}	5.30^{a}	4.46^{a}	4.88^{A}	6.92^{a}	5.46^{bc}	6.19^{A}	9.68^{a}	7.27^{bc}	8.47^{A}	13.92^{a}	9.76^{b}	11.84^{A}
	$CaCl_2$	1.56^{a}	1.76^{a}	1.66^{A}	4.64^{a}	5.29^{a}	4.97^{A}	6.28^{ab}	6.12^{abc}	6.20^{A}	9.12^{ab}	8.73^{ab}	8.93^{A}	11.48^{b}	10.57^{b}	11.03^{A}
	Chitosan	1.41^{a}	1.61^{a}	1.51^{A}	4.10^{a}	4.97^{a}	4.53^{A}	5.27^{c}	5.47^{bc}	5.37^{B}	8.19^{abc}	6.37^{c}	7.28^{B}	9.62^{b}	10.16^{b}	9.89^{A}
	Mixed	1.37^{a}	1.56^{a}	1.47^{A}	4.75^{a}	4.62^{a}	4.69^{A}	6.14^{abc}	5.36^{c}	5.75^{AB}	8.46^{ab}	8.90^{ab}	8.77^{A}	11.29^{b}	10.99^{b}	11.14^{A}
	Main effect (B)	1.53 ns	1.44 ns	-	4.70 ns	4.84 ns	-	6.15 ns	5.60 ns	-	8.91 ns	7.82 ns	-	11.58*	10.37*	-
	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main Effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S2	Control	1.23^{a}	1.31^{a}	1.27^{A}	3.56^{a}	3.59^{a}	3.58^{A}	8.32^{a}	8.14^{a}	8.23^{A}	11.24^{ab}	11.67^{a}	11.45^{A}	14.72^{a}	13.86^{a}	14.29^{A}
	$CaCl_2$	1.23^{a}	1.04^{ab}	1.14^{A}	2.99^{a}	2.60^{a}	2.79^{A}	7.41^{a}	5.43^{b}	6.42^{B}	9.85^{bcd}	8.59^{d}	9.22^{C}	13.82^{a}	11.54^{b}	12.68^{B}
	Chitosan	1.16^{ab}	0.76^{b}	0.96^{A}	3.19^{a}	3.26^{a}	3.23^{A}	7.04^{a}	6.79^{ab}	6.92^{B}	10.81^{abc}	9.72^{bcd}	10.27^{B}	13.95^{a}	12.89^{ab}	13.42^{AB}
	Mixed	0.99^{ab}	1.14^{ab}	1.07^{A}	3.18^{a}	3.27^{a}	3.26^{A}	7.23^{a}	7.32^{a}	7.28^{B}	10.69^{abc}	9.69^{cd}	10.19^{B}	14.29^{a}	13.10^{ab}	13.69^{AB}
	Main effect (B)	1.15 ns	1.06 ns		3.23*	3.18*		7.50 ns	6.92 ns		10.65 ns	9.92 ns		14.19ns	12.85 ns	

Means within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, *=significant ≤0.05, ns: not significant.

Table 4. Effect of spraying treatments on tomato foliage or fruits on fruit visual appearance during different storage days

	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S1	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.77^{b}	5.00^{a}	4.89^{A}	3.55^{bc}	4.65^{a}	4.10^{A}	1.80^{ac}	2.97^{ab}	2.39^{A}	1.33^{d}	2.31^{ab}	1.82^{AB}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.98^{ab}	4.77^{b}	4.89^{A}	3.50^{c}	4.43^{ab}	3.97^{A}	2.34^{abc}	2.04^{bc}	2.19^{A}	1.50^{cd}	1.68^{bcd}	1.59^{B}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.92^{ab}	4.85^{ab}	4.88^{A}	3.78^{abc}	4.42^{abc}	4.10^{A}	2.51^{abc}	2.38^{abc}	2.45^{A}	1.80^{bcd}	2.11^{abc}	1.96^{AB}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.80^{ab}	4.98^{ab}	4.89^{A}	4.00^{abc}	4.45^{ab}	4.22^{A}	2.40^{abc}	3.11^{a}	2.76^{A}	1.52^{cd}	2.53^{a}	2.03^{A}
	Main effect (B)	5.00 ns	5.00 ns	-	4.87 ns	4.90 ns	-	3.71**	4.49**	-	2.26 ns	2.62 ns	-	1.54*	2.16*	-
	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S2	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.83^{a}	4.56^{a}	4.69^{A}	3.61^{a}	3.56^{a}	3.59^{A}	2.17^{ab}	2.65^{a}	2.41^{B}	1.44^{a}	1.56^{a}	1.50^{A}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.61^{a}	4.61^{a}	4.61^{A}	2.95^{ab}	2.42^{b}	2.68^{B}	2.17^{ab}	1.50^{b}	1.84^{C}	1.39^{a}	1.39^{a}	1.39^{A}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.78^{a}	4.78^{a}	4.78^{A}	3.78^{a}	3.95^{a}	3.86^{A}	2.78^{a}	3.08^{a}	2.93^{A}	1.61^{a}	1.39^{a}	1.50^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.78^{a}	4.61^{a}	4.69^{A}	3.22^{ab}	3.50^{a}	3.36^{AB}	2.28^{ab}	2.39^{ab}	2.34^{B}	1.33^{a}	1.22^{a}	1.28^{A}
	Main effect (B)	5.00 ns	5.00 ns	-	4.75 ns	4.64 ns	-	3.39*	3.35*	-	2.35 ns	2.40 ns	-	1.44 ns	1.39 ns	-

Means within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, *=significant ≤0.05, **=highly significant ≤0.01, ns: not significant.

Table 5. Effect of spraying treatments on tomato foliage or fruits on fruit microbial fungi during different storage days

	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S1	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.59^{a}	4.96^{a}	4.78^{A}	3.53^{b}	4.37^{a}	3.95^{A}	2.00^{b}	3.03^{a}	2.52^{AB}	1.47^{c}	2.55^{a}	2.01^{A}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.88^{a}	4.70^{a}	4.79^{A}	3.38^{b}	4.20^{a}	3.79^{A}	2.08^{b}	2.26^{ab}	2.17^{B}	1.51^{c}	1.88^{bc}	1.69^{B}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.82^{a}	4.78^{a}	4.80^{A}	4.24^{a}	4.16^{a}	4.20^{A}	2.57^{ab}	2.47^{ab}	2.52^{AB}	1.94^{bc}	2.20^{ab}	2.07^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.70^{a}	5.00^{a}	4.85^{A}	3.42^{b}	4.53^{a}	3.98^{A}	2.32^{ab}	3.18^{a}	2.75^{A}	1.54^{c}	2.40^{ab}	1.97^{A}
	Main effect (B)	5.00 ns	5.00 ns	-	4.75 ns	4.76 ns	-	3.64*	4.32*	-	2.24*	2.73*	-	1.62*	2.26*	-
	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S2	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.50^{a}	4.56^{a}	4.53^{A}	3.61^{a}	3.56^{a}	3.58^{A}	2.50^{b}	2.83^{b}	2.67^{B}	1.44^{ab}	1.83^{ab}	1.64^{B}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.56^{a}	4.50^{a}	4.53^{A}	2,95^{ab}	2.42^{b}	2.68^{B}	2.33^{bc}	1.42^{c}	1.88^{D}	1.61^{ab}	1.50^{ab}	1.56^{B}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.50^{a}	4.50^{a}	4.50^{A}	3.78^{a}	3.95^{a}	3.86^{A}	3.83^{a}	2.72^{b}	3.28^{A}	2.58^{a}	1.44^{ab}	2.01^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.22^{a}	4.61^{a}	4.42^{A}	3.22^{ab}	3.50^{a}	3.36^{AB}	2.33^{bc}	2.39^{b}	2.36^{C}	1.50^{ab}	1.28^{b}	1.39^{B}
	Main effect (B)	5.00 ns	5.00 ns	-	4.44 ns	4.54 ns	-	3.39*	3.35*	-	2.75 ns	2.34 ns	-	1.78 ns	1.51 ns	-

Means within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, *=significant ≤0.05, ns: not significant.

Table 6. Effect of spraying treatments on tomato foliage or fruits on fruit shrinkage during different storage days

	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S1	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.82^{ab}	5.00^{a}	4.91^{A}	4.06^{ab}	4.20^{a}	4.13^{B}	1.84^{b}	2.65^{ab}	2.25^{A}	1.33^{c}	2.35^{a}	1.84^{AB}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.96^{a}	4.55^{b}	4.76^{A}	3.42^{b}	4.35^{a}	3.89^{B}	2.16^{ab}	2.04^{ab}	2.10^{A}	1.46^{bc}	1.62^{bc}	1.54^{B}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.98^{a}	4.84^{ab}	4.91^{A}	4.73^{a}	4.47^{a}	4.60^{A}	2.69^{ab}	2.36^{ab}	2.53^{A}	2.04^{ab}	2.11^{ab}	2.08^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.92^{ab}	5.00^{a}	4.96^{A}	3.38^{b}	4.71^{a}	4.05^{B}	2.38^{ab}	2.87^{a}	2.63^{A}	1.66^{bc}	1.98^{abc}	1.82^{AB}
	Main effect (B)	5.00 ns	5.00 ns	-	4.92 ns	4.85 ns	-	3.90 ns	4.43 ns	-	2.27 ns	2.48 ns	-	1.62**	2.02**	-
	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S2	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.83^{a}	4.56^{a}	4.69^{A}	3.39^{ab}	3.57^{a}	3.48^{B}	2.45^{abc}	2.35^{abc}	2.40^{B}	1.61^{a}	1.56^{a}	1.59^{A}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.56^{a}	4.39^{a}	4.48^{A}	3.33^{ab}	2.83^{b}	3.08^{B}	2.22^{bc}	1.67^{c}	1.95^{C}	1.39^{a}	1.39^{a}	1.39^{A}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.61^{a}	4.83^{a}	4.72^{A}	3.89^{a}	4.00^{a}	3.95^{A}	2.72^{ab}	3.17^{a}	2.94^{A}	1.67^{a}	1.50^{a}	1.59^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.61^{a}	4.44^{a}	4.53^{A}	3.28^{ab}	3.67^{a}	3.48^{B}	2.22^{bc}	2.33^{abc}	2.28^{BC}	1.61^{a}	1.33^{a}	1.47^{A}
	Main effect (B)	5.00 ns	5.00 ns	-	4.65 ns	4.56 ns	-	3.46*	3.52*	-	2.40*	2.38*	-	1.57 ns	1.45 ns	-

Means within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, *=significant ≤0.05, **=highly significant ≤0.01, ns: not significant.

Table 7. Effect of spraying treatments on tomato foliage or fruits on fruit firmness during different storage days

	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S1	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.65^{c}	5.00^{a}	4.83^{A}	3.94^{b}	4.74^{a}	4.34^{A}	2.59^{b}	3.66^{a}	3.13^{A}	1.71^{d}	3.00^{a}	2.36^{A}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.76^{abc}	4.74^{bc}	4.75^{A}	4.12^{ab}	4.44^{ab}	4.28^{A}	3.12^{ab}	3.15^{ab}	3.14^{A}	2.02^{cd}	2.30^{bcd}	2.16^{A}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.88^{abc}	4.71^{c}	4.80^{A}	4.31^{ab}	4.49^{ab}	4.40^{A}	3.37^{ab}	3.47^{a}	3.42^{A}	2.20^{bcd}	2.78^{ab}	2.49^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.70^{c}	4.98^{ab}	4.84^{A}	3.98^{b}	4.69^{a}	4.34^{A}	3.02^{ab}	3.60^{a}	3.31^{A}	2.14^{bcd}	2.64^{abc}	2.39^{A}
	Main Effect (B)	5.00 ns	5.00 ns	-	4.75 ns	4.86 ns	-	4.09**	4.59**	-	3.02*	3.47*	-	2.02*	2.68*	-
	Treatment (A)	Day 1		Main effect (A)	Day 3		Main effect (A)	Day 6		Main effect (A)	Day 9		Main effect (A)	Day 12		Main effect (A)
		F	GM		F	GM		F	GM		F	GM		F	GM	
S1	Control	5.00^{a}	5.00^{a}	5.00^{A}	4.89^{a}	4.67^{a}	4.78^{A}	3.67^{a}	3.72^{a}	3.69^{A}	2.78^{a}	2.40^{ab}	2.59^{AB}	2.22^{a}	1.83^{a}	2.03^{A}
	$CaCl_2$	5.00^{a}	5.00^{a}	5.00^{A}	4.78^{a}	4.56^{a}	4.67^{A}	3.67^{a}	3.50^{a}	3.59^{A}	2.56^{ab}	1.75^{b}	2.16^{B}	1.94^{a}	1.67^{a}	1.81^{A}
	Chitosan	5.00^{a}	5.00^{a}	5.00^{A}	4.72^{a}	4.67^{a}	4.69^{A}	4.11^{a}	4.17^{a}	4.14^{A}	3.22^{a}	3.06^{a}	3.14^{A}	2.61^{a}	2.11^{a}	2.36^{A}
	Mixed	5.00^{a}	5.00^{a}	5.00^{A}	4.83^{a}	4.83^{a}	4.83^{A}	3.67^{a}	4.06^{a}	3.87^{A}	2.33^{ab}	2.67^{ab}	2.50^{B}	1.78^{a}	1.61^{a}	1.69^{A}
	Main effect (B)	5.00 ns	5.00 ns	-	4.81 ns	4.68 ns	-	3.78 ns	3.86 ns	-	2.72 ns	2.47 ns	-	2.14 ns	1.81 ns	-

Means within rows and columns denoted by different letters indicate significant differences according to Duncan's test at P<0.05. S1: season 1, S2: season 2, F: foliar, GM: green mature, *=significant ≤0.05, **=highly significant ≤0.01, ns: not significant.

All F plants sprayed with $CaCl_2$, chitosan, or mix treatments had significantly lower lycopene content (Figure 1) and flavonoid contents (Figure 2) than the control. However, GM plants had significantly higher lycopene content, total phenolic compounds content, and flavonoids with all spraying treatments than the control (Figures 1, 2, and 3). In GM plants, the highest lycopene and total phenol contents were in mixed treatments, followed by chitosan, whereas the highest flavonoids content was in chitosan treated plants (Figures 1, 2, and 3).

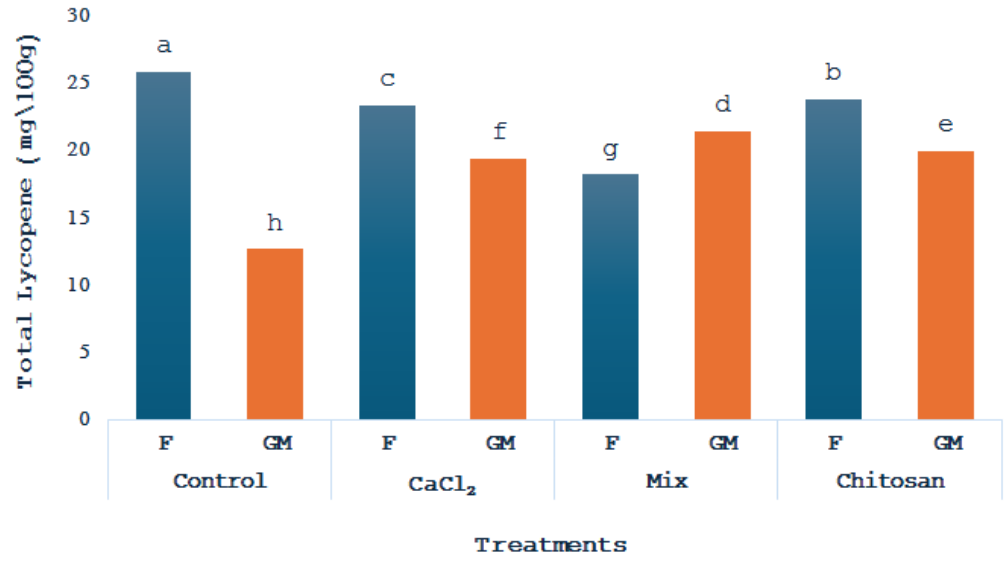

Figure 1. Total lycopene content (mg/100g) in tomato fruits as affected by spraying treatments on different plant organs (F: foliar or GM: green mature).

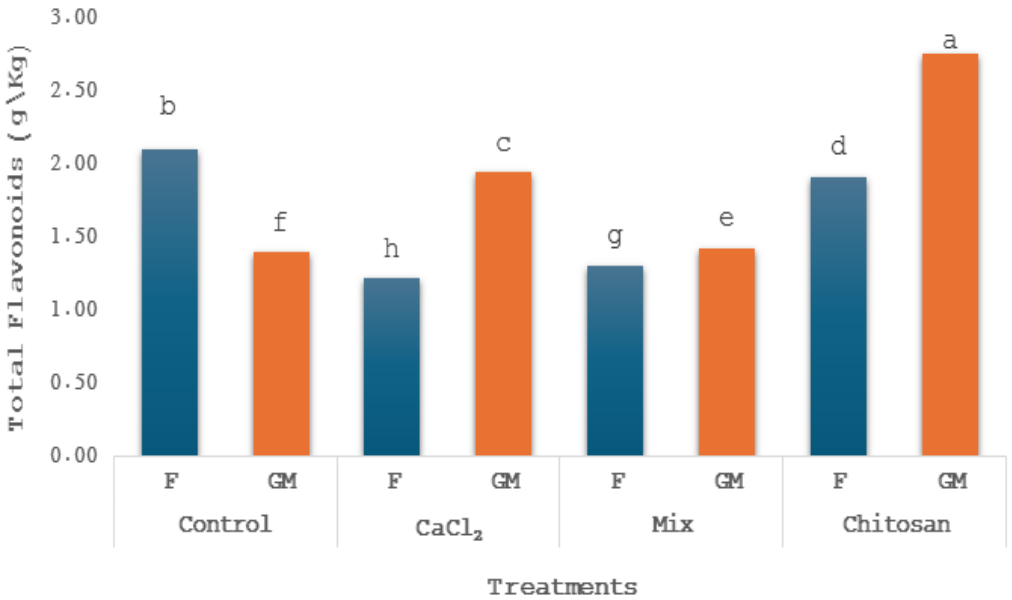

Figure 2. Total flavonoid content (g/kg) in tomato fruits as affected by spraying treatments on different plant organs (F: foliar or GM: green mature).

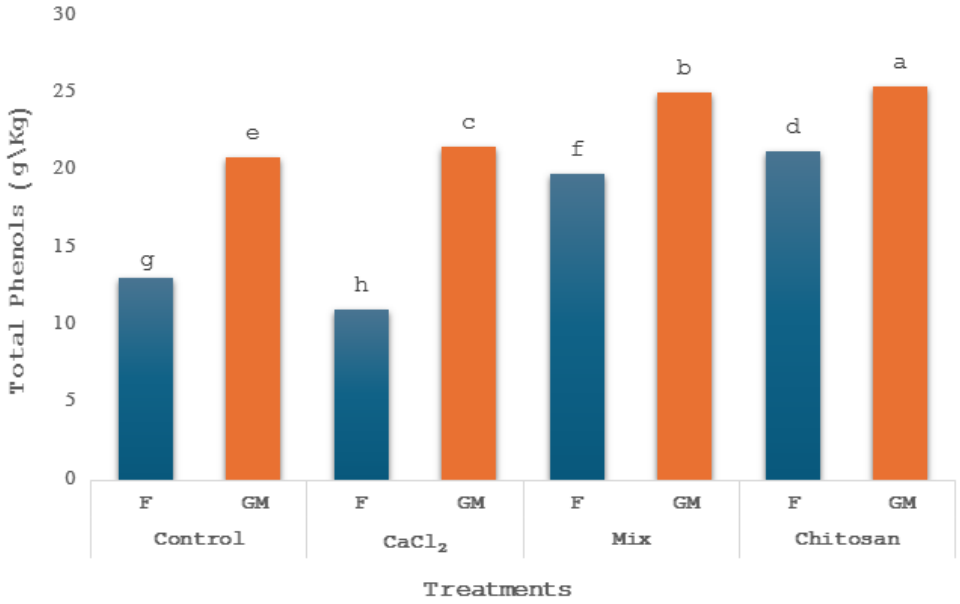

Figure 3. Total phenols content (g/kg) in tomato fruits as affected by spraying treatments on different plant organs (F: foliar or GM: green mature).

Discussion

The results of this experiment showed insignificant effects of treatments or spraying of different plant organs on tomato growth traits such as plant height, branches number, and stem diameter. However, F plants sprayed with $CaCl_2$ had significantly the widest stems in S1, although not significant, it was still the widest in the second season. Plants sprayed with $CaCl_2$ had higher fruit number than most of the treatments, whether sprayed at F or GM, whereas plants sprayed with chitosan had the lowest fruit number (except in S2 at F plants). Interestingly, F plants sprayed had significantly higher fruit number than those of GM plants. As for the yield, F plants sprayed with $CaCl_2$ always had significantly higher fruit yield than those GM plants except for the mixed treatments in S2. Also, F plants sprayed with $CaCl_2$ had the highest fruit yield. At GM, control plants followed by those sprayed with $CaCl_2$ had the highest yields in S1, whereas in S2, the highest was in $CaCl_2$ plants, followed by mix treatment.

Calcium is a main plant macronutrient that affects the formation of cell walls and plasma membrane development. It is essential for plant growth and development, and is considered an important intracellular messenger, facilitating responses to different developmental processes, hormones, and stress signals (Madani *et al.,* 2015; Niu *et al.*, 2021; Xu *et al.*, 2013). Nevertheless, calcium is considered an immobile element (Niu *et al.,* 2021). For this reason, constant supply of calcium is needed by plants for vigorous growth and development which can be accomplished through foliar sprayings (Madani *et al.,* 2015; Niu *et al.,* 2021; Xu *et al.*, 2013). Indeed, Santos *et al.*, 2023, revealed that $CaCl_2$ was the most efficient Ca^{2+} source for tomato plants (Santos *et al.,* 2023). In agreement with the current results, a significant improvement was observed in the growth and yield of tomato plants with foliar application of calcium chloride which indicated a positive correlation between plant growth and application of calcium chloride (Ayyub *et al.*, 2012). Foliar calcium application

(particularly 5 and 10mM Ca) was also found to improve tomato growth, yield, and fruit quality such as TSS whether without salt stress or under salt stress conditions (Islam *et al*., 2023).

From the above results, it is observed that foliar application of chitosan treatment did not improve the growth or yield of tomato plants. In contrary to this work, Hussain *et al.* (2019) found that pre-harvest foliar spray of chitosan enhanced growth characteristics and quality attributes of tomatoes under plastic tunnel conditions. Moreover, a positive effect of chitosan was found on the growth, and hence yield, soluble solids and vitamin C of tomato fruits (Zandian *et al.*, 2023).

In this experiment, the weight loss of fruits increased by increasing storage days. Foliar sprayed plants had a lower weight loss with $CaCl_2$, chitosan, and mix treatments in S1 and with $CaCl_2$ and chitosan in S2. Also, in GM plants in S2, $CaCl_2$ treatments had significantly lower fruit weight loss than the control after 12 days of storage. In agreement with the current results, Mazumder *et al.* (2021) found that spraying with 2% of $CaCl_2$ gave lower weight loss and showed a decline in disease incidence. Also, Tagele *et al.*, 2022, found that pre-harvest applications of $CaCl_2$ and chitosan decreased weight loss of tomatoes after 4, 8, and 12 days at ambient storage conditions (Tagele *et al*., 2022). Chitosan is known to have gaseous barrier properties and was found to reduce the rate of respiration and carbon dioxide production rate (Olawuyi *et al.,* 2019). In addition, $CaCl_2$ solutions were found to transiently inhibit respiration by forming a transient barrier to CO_2 and O_2 exchange between the fruit tissue and the surrounding atmosphere (Saftner *et al.,* 1999).

In this work, in S1 only at F plants, those sprayed with $CaCl_2$, chitosan, and mixed treatments had better visual appearance than control fruits after 12 days of storage. Lower shrinkage score was observed in fruits of the chitosan treatment in F plants after 12 days of storage in S1. Regarding the firmness of fruits, all foliar sprayed treatments gave significantly better fruit hardness after 12 days of storage than the control in S1 only.

From the above results, it could be concluded that foliar sprayed plants with $CaCl_2$ or chitosan, had lower fruit loss and showed an improvement on visual appearance and hardness of fruits but that was in S1 only. In a study by Melo *et al.* (2022), foliar application of calcium (calcium chloride or calcium acetate) was effective in increasing the initial fruit firmness of tomatoes regardless of the frequency of spraying (Melo *et al.*, 2022). In another study, Matteo *et al.* (2002) observed that the firmness of tomato fruits was not affected by calcium foliar application when sprayed after 39 and 62 days of full bloom, however firmness was improved only when was sprayed after 26 days of full bloom as compared to the control (Matteo *et al.*, 2022). In contrary to the current work, foliar application of chitosan was found to stimulate the coloring and softening of tomato fruits as compared to controls (Zheng *et al.*, 2023). Also, none of the different foliar calcium products or methods of application changed fruit quality, firmness, or shelf life in any crop (strawberry, raspberry, blackberry, or blueberry) or cultivar tested (Vance *et al.*, 2017) .

Chitosan, on the other hand, showed an enhancement in the controlling of microbial fungi in foliar sprayed plants in this experiment. Chitosan has been shown to be an effective natural antimicrobial agent. It has amino groups available to interact with microbial cell walls when sprayed on fruits and vegetables causing vital death of bacteria and fungi through cell lysis mechanisms. It controls respiration rate, weight and water loss, without affecting odor or taste of fruits and vegetables (Duan *et al.*, 2020).

Lycopene is an important pigment and the most abundant carotenoid in ripened fruits, responsible for the appearance of the tomato's red deep color. Other important plant components are the phenolic and flavonoids compounds that are responsible for antioxidant activity. In this work, lycopene contents, flavonoids, and total phenolic contents were significantly higher in GM plants sprayed with different treatments than the control. The highest lycopene and total phenol contents were obtained in mixed treatments, followed by chitosan, whereas the highest flavonoids content was in chitosan treated plants. This comes in agreement with Shao *et al.* (2022), who observed that that chitosan treatment on mature green tomatoes improved fruit quality such as skin color, content of carotenoids (lycopene and β-carotene) and vitamin C. Contrary to this work, tomato fruits of mature green stage treated with 2% $CaCl_2$ showed a delay in color development (lycopene content). Also, the effect of $CaCl_2$ (1, 1.5, or 2%) on total phenolic content showed that they were not significantly different from the control treatments (Mazumder *et al.* 2021).

However, lycopene contents, flavonoids, and total phenolic contents were significantly lower in all spraying treatments in foliar sprayed plants than in the control. The delay in lycopene formation in this experiment with foliar application with $CaCl_2$ may be attributed to the reduction in pectin substances and to the lower cell wall degradation enzymes. Indeed, calcium interacts with pectin to form complexes in the cell wall which plays a key role in preserving cell wall structure, hence reducing the activity of cell wall degrading enzymes (Khaliq *et al.*, 2015; Sati and Qubbaj, 2021). The reduction in lycopene, phenols and flavonoids in tomato fruits with chitosan treatment in F plants in this experiment comes also in agreement with work done by Hernández *et al.* (2002) who found that chitosan aerial spraying treatment (1 g/L) increased tomato yield due to the rise in the number of fruits, however it produced a significant decrease in the concentration of lycopene, vitamin C, lutein, β-carotene, and flavanols. Similarly, pre-harvest applications of $CaCl_2$ (1%) and chitosan (0.1, 0.3, and 0.5%) did not differ in lycopene content of tomato fruits from the control after 4, 8, and 12 days of storage at ambient storage conditions, while on day 16, the highest lycopene content was recorded in the control treatment (Tagele *et al.*, 2022). This is attributed as the lycopene value may be depending on the dose and mode of application. A study by Parvin *et al*. (2019) revealed that different chitosan application methods affected tomato quality as chitosan treatments based on foliar spraying alone decreased lycopene concentration in the fruit, whereas combined foliar and soil application of chitosan increased lycopene concentration when compared to control fruits.

Overall, this study revealed that the pre-harvest application of $CaCl_2$, mainly when sprayed at plant foliage, could improve growth and yield to some extent and at the same time extend the postharvest longevity mostly through increasing the firmness and delaying lycopene content of tomato fruits. Also, foliar spraying of chitosan was primarily beneficial for postharvest stage only as weight loss and fungal growth were decreased while firmness, visual appearance, and color of fruits were maintained when stored for up to 12 days at ambient conditions. We can conclude that $CaCl_2$ was the best treatment for tomato growth and yield, concomitant with improving fruit visual appearance and firmness, and for delaying skin color development, whereas foliar spraying of chitosan can be used for better postharvest fruit characteristics only.

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تأثير الرش ما قبل الحصاد لكلوريد الكالسيوم والكيتوزان ومزيجهما على نمو الطماطم والمحصول وخصائص الثمرة وجودتها

حسناء محمود عبد العليم، محمد حمام الدقيشي، ريهام محمد عبد الله*

قسم الخضر، كلية الزراعة، جامعة أسيوط، اسيوط، مصر.

الملخص

تشكل خسائر ما بعد الحصاد عقبة كبيرة تقلل من إنتاج الطماطم في العديد من البلدان النامية، بما في ذلك مصر. أجرى بحث لتقييم تأثير معاملات ما قبل الحصاد على نمو وإنتاجية الثمار وجودتها وخصائص الثمار لصنف الطماطم هجين نورا 765'. تضمنت التجربة أربع معاملات رش هي معاملة الكنترول (بدون رش) وكلوريد الكالسيوم ($CaCl_2$ 1.5%) والكيتوزان 1.5%، وخليط بينهما والرش على جزئيين مختلفين من النبات، الاوراق أو الثمار في طور النضج الأخضر. كانت النباتات التي تم رشها ب ($CaCl_2$ 1.5%) على الاوراق تحتوي على اطول النباتات وأكبر قطر في السيقان. كما أن النباتات كانت ذات عدد ثمار أعلى عن معظم المعاملات سواء تم رشها على الاوراق او على الثمار. حصلت النباتات في مرحلة الرش الورقي التي تم رشها بكلوريد الكالسيوم على اعلى إنتاجية للثمار كما كان لها فقدان أقل للوزن. النباتات التي تم رشها في مرحلة الرش الورقي خلال الموسم الاول فقط، كانت معاملات كلوريد الكالسيوم، والكيتوزان وخليطهما ذات مظهر عام وصلابة أفضل عن ثمار الكنترول بعد 12 يوما من التخزين. النباتات التي تم رشها في مرحلة الرش الورقي بمعاملة الكيتوزان كانت بها اصابات فطرية أقل بكثير عن معاملة الكنترول. كانت محتويات الليكوبين والفلافونيدات والمحتوى الفينولي الكلى التي تم رشها في مرحلة النضج الأخضر كان بها أعلى مستويات عنها في الكنترول بينما تلك التي تم رشها في مرحلة الرش الورقي كانت أقل عن الكنترول. يمكننا ان نستنتج ان معاملة رش كلوريد الكالسيوم ورقياً كانت أفضل لنمو الطماطم وانتاجيتها ولتحسين المظهر العام للثمار وتأخير تدهورها بينما يمكن رش الكيتوزان ورقياً لتحسين خصائص الثمار بعد الحصاد.

الكلمات المفتاحية: *الصلابة، العدوى الميكروبية، الليكوبين، المظهر البصري للثمرة، فقدان وزن الثمرة*