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EVALUATION OF $Ca(NO_3)_2$ AND VARIOUS CONTAINER CELL SIZE EFFECTS ON SOME GROWTH ATTRIBUTES AND NUTRIENT CONTENT OF TOMATO TRANSPLANTS

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ABSTRACT

Optimizing container cell size and nutrition is crucial for enhancing the quality of vegetable transplants. The current study evaluated the effect of different cell sizes and $Ca(NO_3)_2$ on some properties of tomato (*Solanum lycopersicum* L.) transplants. Experimental treatment included four levels (0, 50, 100, and 150 mg L^{-1}) of $Ca(NO_3)_2$ and 5 different cell sizes of containers (1, 2, 3, 4, and 5) in a factorial experiment based on a completely randomized design (CRD) with three replications under greenhouse conditions. $Ca(NO_3)_2$ and larger cell size, increased height, stem diameter, fresh and dry weights of roots and shoots, and concentration of chlorophyll, protein, SPAD, carbohydrates, and macro/micronutrients. The results revealed that maximum shoot and root fresh and dry weight, photosynthesis pigments, N, P, K, Ca, and Fe concentrations were recorded at 150 mg L^{-1} × cell size 5. In comparison, the highest Zn and Mn concentrations were recorded at 100 mg L^{-1} × cell size 4 and 5. Our results demonstrated that applying $Ca(NO_3)_2$ and increasing the cell size of the containers improved the traits evaluated, so $Ca(NO_3)_2$ at 10 and 15 mg L^{-1} with cell size 5 can be recommended to transplant producers.

Key words: calcium, carbohydrate, containers, nitrogen, nutrient uptake, *Solanum lycopersicum*

INTRODUCTION

The first objective of vegetable transplanting is to provide higher-quality seedlings quickly [Moncada et al. 2020]. In addition, transplantation can reduce water consumption and damage from pests and diseases, shorten the growing season, and protect crops from wind and birds [Safi et al. 2019]. Polystyrene multicellular containers come in a variety of shapes and cell sizes. When selecting trays for vegetable transplants, it is crucial to consider the number of cells in the container. The container's size directly impacts the growth

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of shoots and roots, dry matter partitioning, standard establishment, reproductive development, and early yield. Therefore, choosing the appropriate container size is essential to achieve optimum results [Leskovar 2020]. The tray's selected cell size or volume greatly influences greenhouse tomato transplants' growth. While larger cells offer more space for better transplant growth, increasing the cell volume or size means more space is needed to produce the transplants. It is, therefore, crucial to determine the appropriate cell size that can produce healthy and robust transplants [Salari et al. 2022]. The size of the cells in the transplant tray has been reduced, which limits the amount of space and oxygen available for root growth and metabolic activities. This reduction in space and oxygen availability hurts the absorption of nutrients by the transplants. As a result, the photosynthetic capacity and production of cultured material in seedlings are also negatively affected [Shopova and Cholakov 2014]. The optimal cell size for seedling growth should be chosen based on the root characteristics of each plant [Balliu et al. 2017].

A further important factor for producing quality seedlings is improving the fertilization regime. One of the most important aspects of good transplant production is achieving a well-developed and functional root system that can provide mechanical support and nutrient uptake to the transplant. Due to the importance and value of vegetables and the need to utilize many nutrients in their production, proper nutrition is one of the basic transplant principles. The growth rate of vegetable transplants may be regulated by controlling the concentration of N and other nutrients in the cultivation medium. N is one of the essential components of cell walls, protein structure, nucleic acids, chlorophyll, enzymes, phosphatides, many vitamins, and other organic molecules. It plays a vital role in plant biochemistry; N is also influential and essential in plant metabolic processes [Dehnavard et al. 2017]. In addition, N enhances the growth of green and photosynthetic plant tissues such as leaves and increases the leaf area index due to its presence in the chlorophyll structure [Rens et al. 2018]. N fertilizers generally result in better and more balanced nutrition, improving plant growth and producing more vigorous seedlings for transport to more remote areas [Mekdad 2015]. Another typical fertilizer used in transplanting is calcium (Ca), which plants absorb as a divalent cation (Ca^{2+}) and is essential for growth, development, increasing yield, and fruit quality. It is also linked directly to the structure, stability, and regulation of cell walls and membranes and is essential for cell division processes and various enzyme activations [Buchanan et al. 2015]. In addition, Ca can inactivate polygalacturonase (PG), which destroys cell wall materials such as pectin; thus, Ca has great potential in agricultural systems [Chakraborty et al. 2015]. Plants require calcium as a mineral, which can be provided in different forms, such as calcium chloride, calcium nitrate, calcium sulfate, and lime. According to experts, calcium nitrate is a highly soluble and efficient source of calcium that has shown promising results in delivering the necessary amount of calcium to plants [Coelho et al. 2021]. Calcium nitrate is commonly used as a water-soluble primary fertilizer and standard hydroponic nutrient solution [Wu et al. 2023]. Applying a foliar spray containing $Ca(NO_3)_2$ proved effective in correcting deficiencies of both calcium and nitrogen in plants. It led to a notable increase in the concentrations of these essential macronutrients in the leaves. As a result, the critical concentration of these two elements may not be of primary importance, as the foliar spray addressed the deficiencies and improved the plant's overall health [Kaya et al. 2002]. Several studies have looked at the nutrition of vegetable seedlings with N and Ca to achieve appropriate plant growth. Abdelgadir et al. [2005] reported that applying 7–14 mM N significantly increased shoot dry weight in transplanted tomato plants. In this context, Singh et al. [2021] reported that nitrogen application increased the number of leaves, lateral branches, and leaf area index. In a study on transplanted tomato plants, Shafeek et al. [2013] reported that the highest plant height and leaf area were achieved with Ca application. Ayyub et al. [2012] also demonstrated that soil application of Ca significantly increased the plant height of tomato transplants compared to the control.

Tomato (*Solanum lycopersicum* L.) is one of the most important vegetables in the world, contains significant amounts of essential vitamins, minerals, and global distribution, and responds positively to transplanting [Srivastava et al. 2020]. Transplanting plays an influential role in improving the utilization of inputs such as seeds and fertilizers, and also in in-

creasing germination percentage efficiency, achieving optimum planting density, more effective control of pests, diseases, and weeds, and thus reducing the shortening of the season and production costs [VanTine et al. 2003]. Seedling quality depends on light, temperature, CO_2, moisture, water supply, fertilization, culture medium, and plant genotype [Brazaitytė et al. 2010].

The above studies demonstrate the use of Ca and N to improve plant growth and development and their physiological, biochemical, and nutritional properties. However, the cell size potential has yet to be reported. Therefore, this study aimed to assess the effect of different cell sizes containing soil as a culture medium in various combinations with calcium nitrate on the morphological, biochemical, and nutritional properties of transplanted tomato plants under greenhouse conditions.

MATERIAL AND METHODS

Measurement of morphological traits. The seeds of *Solanum lycopersicum* cv. Super chief El Dorado, California, USA, was provided by Pakan Bazr Company, Isfahan. Iran and were cultivated in a greenhouse under 27 ±5°C, with a humidity of 75–80% and a light intensity of 250 µmol m^2. This research was conducted in a factorial experiment based on a completely randomized design (CRD) with three replications in the Department of Horticultural Sciences, Maragheh University greenhouse during spring 2021. Experimental treatments included four levels (0, 50, 100, and 150 mg L^{-1}) of calcium nitrate ($Ca(NO_3)_2$. $2H_2O_2$) and five different cell sizes of containers characterized in Table 1. Plastic containers were filled with soil, and their physical and chemical properties are presented in Table 2. Two tomato seeds were sown in each cell at a depth of 0.5 cm, and one plant was left after germination. After the true leaf of transplant emergence, calcium nitrate treatment was applied three times weekly. Containers were irrigated daily with tap water to 80% of field capacity.

Plant morphological traits were recorded at harvest, including plant height, stem diameter, and fresh and dry weights of roots and shoots. For this purpose, three plants from each treatment were randomly selected to measure the traits. The shoot and root weights were calculated separately using a digital scale (Bp211D, Sartorius, Germany, with an accuracy of 0.0001 g). Plant samples were kept in an oven (UF750 PLUS, Memmert, Germany) at 75°C for 48 h to fix the weight and measure dry weight. A digital caliper was also used to measure the head diameter. The transplants' three fully expanded young leaves were chosen to measure SPAD value, and an average of them was noted as SPAD value for each replication.

Pigment photosynthesis. The Arnon [1967] method was used to measure the content of chlorophylls *a* and *b* (Chl *a* and *b*) and carotenoids (CARs). 0.5 g of fresh leaves were crushed with liquid nitrogen to obtain a homogeneous extract, and 5 ml of 80% acetone was added. After centrifuging the mixture at 10,000 rpm for 10 minutes, we measured the absorbance of the supernatant using a spectrophotometer (UV-1800, Shimadzu, Japan) at 663, 645, and 470 nm. 80% acetone was used as a blank to calibrate the device. Chl a, Chl b, and carotenoid concentrations were calculated using the following formulas.

$$Chl_a \text{ (mg g}^{-1} \text{ FW)} = [12.7(A663) - 2.79(A645)]$$
$$Chl_b \text{ (mg g}^{-} \text{ FW)} = [21.50\ (A645) - 5.10(A663)]$$
$$CARs \text{ (mg g}^{-1} \text{ FW)} = [1000(A470) - 1.82Ca - 85.02Cb] / 198$$

A663 refers to the absorbance at 663 nm, A645 is the absorbance at 645 nm, and A470 is the absorbance at 470 nm. The absorbance coefficients for the red peak of Chl a are 12.7, and for the red peak of Chl b, are 2.69. The absorbance coefficients for the blue peak of carotenoids are 1000, 1.82, and 85.02.

Total soluble protein. The Bradford method measured the total soluble protein content [Bradford 1976]. It was extracted 0.2 g of fresh weight by homogenizing it in 1.5 ml of 50 mM Na buffer phosphate (pH: 7.8), which had 1 mM EDTA and 2% (w/v) polyvinylpolypyrrolidone. The homogenized extracts were centrifuged at 10,000 rpm for 15 minutes at 4°C. The supernatants were applied to determine the total soluble protein. To standardize the measurement, we used bovine serum albumin (BSA) containing 0, 0.2, 0.4, 0.6, 0.8, or 1 mg ml^{-1} with 100 µl of Bradford solution. To create the Bradford reagent, 25 mg of Coomassie Brilliant Blue G-250 was dissolved in 25 ml of methanol and 50 mL of 85% (w/v) phosphoric acid. After adding the solution to 850 ml of distilled water and filtering it through Whatman filter

Table 1. Transplant container characteristics used in this experiment

Model	Length (cm)	Area (in^2)	Depth (cm)	Diameter hole (cm)	Cell number
1	50	50.24	4	4	128
2	50	88.31	5	4.5	96
3	50	117.75	6	5	72
4	50	137.37	7	5	45
5	50	155.43	9	5.5	24

Table 2. Physicochemical properties of soil used in this experiment

EC ($ds\ m^{-1}$)	pH	Potassium	Phosphorus	Calcium	Nitrogen	Organic carbon	Soil pattern
		(%)			mg kg^{-1}		
1.26	7.49	0.62	0.06	1.52	20.13	802.7	loamy

paper #1, 1 ml of the resulting mixture was added to 50 µl of extract. It was then incubated for 5 minutes at room temperature before measuring its absorbance at 595 nm.

Chlorophyll index (SPAD). To obtain the chlorophyll index of the tomato plant, a chlorophyll meter reading was taken using the SPAD 502 from Minolta Ltd. in Osaka, Japan. The middle part of three leaf blades was measured for SPAD values, and an average of those samples was recorded.

Macro- and micro-nutrient concentration. The following methods determined the K, N, P, Mn, Fe, and Zn concentrations in tomato transplant samples. K concentration was determined using a flame photometer, while the Kjeldahl method was used to measure N concentration and the yellow method for P concentration. An atomic absorption spectrometer was used to measure Mn, Fe, and Zn concentrations. The concentration of P was determined at 470 nm using a spectrophotometer, with vanadate-molybdate used as an indicator. These methods were adopted from studies by Tandon et al. [1968] and Jones [1972].

Total carbohydrate content. The total carbohydrate content of a fresh tomato leaf was measured by extracting 0.5 g of it using 10 ml of 95% ethanol for an hour in a water bath at 80°C. The mixture was then centrifuged at 12000 rpm for 10 minutes. The resulting supernatant was taken, and 1 ml of 0.5% phenol and 5 ml of 98% sulfuric acid were added. The absorption was measured at 483 nm using a spectrophotometer, as described in Chen et al. [2002].

Statistical analysis. To analyze our data, we used the MSTAT-C ver. 2.1 software and conducted ANOVA analysis. The comparison of mean data was analyzed with the utmost care, using the least significant difference (LSD) test at a 5% probability level. For a visual representation of the comparison of means, we utilized office collection software to create graphs that accurately illustrate our findings.

RESULTS

Morphological traits. Our results revealed that different $Ca(NO_3)_2$ concentrations and cell size of containers improved morphological traits (Fig. 1). The effect of container cell size was significant on plant height at a 1% probability level (Tab. 3). The highest plant height (15.25 cm) was obtained for cell size 5, which increased to 71.83% compared to the control. The lowest plant height (8.875 cm) was related to cell size 1 (Fig. 2a). The results also showed that the plant height of tomato seedlings was significantly affected by different levels of $Ca(NO_3)_2$ fertilizer at $P \leq 0.01$ (Tab. 3). The highest plant height (13.23 cm) was obtained at 150 mg L^{-1} $Ca(NO_3)_2$, showing a 42.25% increase over the lowest plant height (9.300) measured in the control (Fig. 2b).

The results demonstrated that the application of different $Ca(NO_3)_2$ levels and cell size of transplant containers had a significant effect on fresh weight (FW) and dry weight (DW) of roots and shoots, stem

Table 3. Effect of $Ca(NO_3)_2$ and different cell size containers on morphological characteristics of tomato transplants

Cell size model	$Ca(NO_3)_2$ (mg L^{-1})	Shoot FW (g)	Shoot DW (g)	Root FW (g)	Root DW (g)	Leaf number	Stem diameter (mm)
1	0	0.67 ±0.113 j	0.092 ±0.0046 i	0.31 ±0.007 m	0.040 ±0.0010 m	5.7 ±0.472 m	2.09 ±0.025 j
	50	0.78 ±0.025 j	0.182 ±0.0085 h	0.40 ±0.020 l	0.070 ±0.0031 l	5.3 ±0.464 m	2.35 ±0.012 i
	100	0.83 ±0.057 j	0.219 ±0.0026 g	0.43 ±0.015 l	0.079 ±0.0025 jl	7.3 ±0.099 l	2.90 ±0.070 g
	150	1.26 ±0.005 g	0.473 ±0.0850 d	0.72 ±0.012 i	0.109 ±0.0043 gh	10.7 ±0.471 hi	3.09 ±0.040 f
2	0	0.82 ±0.014 j	0.184 ±0.0054 h	0.43 ±0.010 l	0.069 ±0.0053 i	14.0 ±0.241 f	3.42 ±0.029 d
	50	0.93 ±0.028 li	0.190 ±0.0029 h	0.52 ±0.009 k	0.076 ±0.0042 kl	8.3 ±1.116 kl	2.69 ±0.068 h
	100	1.25 ±0.022 g	0.227 ±0.0034 g	0.64 ±0.015 j	0.125 ±0.0094 fg	10.7 ±1.203 hi	2.84 ±0.029 g
	150	1.80 ±0.042 de	0.614 ±0.0008 b	1.14 ±0.018 e	0.181 ±0.0111 d	12.0 ±0.471 gh	3.03 ±0.026 f
3	0	0.96 ±0.062 hj	0.192 ±0.0084 h	0.52 ±0.015 k	0.092 ±0.0066 ik	16.0 ±0.463 e	3.33 ±0.062 de
	50	1.15 ±0.014 gj	0.214 ±0.0104 g	0.63 ±0.019 j	0.094 ±0.0097 hj	20.3 ±0.816 c	3.61 ±0.046 c
	100	2.35 ±0.037 c	0.510 ±0.0107 c	0.73 ±0.064 i	0.170 ±0.0065 d	9.0 ±0.943 jk	2.68 ±0.042 h
	150	3.80 ±0.046 b	0.658 ±0.0014 a	1.59 ±0.048 c	0.283 ±0.0060 b	11.7 ±0.826 hi	2.87 ±0.063 g
4	0	1.11 ±0.033 gj	0.266 ±0.009 f	0.60 ±0.007 j	0.105 ±0.0080 hi	14.3 ±0.471 f	3.03 ±0.054 f
	50	1.58 ±0.012 f	0.288 ±0.0204 ef	0.78 ±0.010 h	0.143 ±0.0090 e	17.7 ±0.843 d	3.37 ±0.082 d
	100	2.27 ±0.077 c	0.481 ±0.0147 d	1.13 ±0.017 e	0.225 ±0.0071 c	25.3 ±0.716 b	3.61 ±0.017 c
	150	4.15 ±0.112 a	0.653 ±0.0142 a	1.71 ±0.034 b	0.291 ±0.0141 b	10.3 ±0.471 ij	3.05 ±0.065 f
5	0	1.51 ±0.034 f	0.282 ±0.0094 ef	0.96 ±0.011 g	0.125 ±0.0041 fg	13.3 ±0.943 fg	3.25 ±0.125 e
	50	1.59 ±0.229 ef	0.293 ±0.0177 e	1.05 ±0.057 f	0.135 ±0.0045 ef	14.7 ±1.247 ef	3.58 ±0.056 c
	100	1.84 ±0.063 d	0.474 ±0.0295 d	1.25 ±0.015 d	0.224 ±0.0033 c	19.7 ±0.921 c	3.77 ±0.071 b
	150	4.21 ±0.050 a	0.651 ±0.0342 a	1.90 ±0.008 a	0.310 ±0.0017 a	27.7 ±0.375 a	3.93 ±0.014 a
S. O. V.	df						
Cell size	4	13.672**	0.475**	2.291**	0.073**	344.275**	2.019**
$Ca(NO_3)_2$	3	3.595**	0.015**	0.839**	0.021**	207.311**	1.404**
Cell size × $Ca(NO_3)_2$	12	0.512**	0.003**	0.031**	0.001**	86.900**	0.033**
Error	40	0.017	0.000	0.001	0.000	1.017	0.005
C.V.		7.48	4.96	3.69	5.74	7.36	2.22

** significant at the 1% probability levels. S.O.V., FW, and DW refer to the source of variation, fresh weight, and dry weight

Fig. 1. The effect of different levels of $Ca(NO_3)_2$ and cell size of transplant containers on growth, a (without $Ca(NO_3)_2$ + cell size 1, 2, 3, 4 and 5, respectively), b (50 mg L–1 $Ca(NO_3)_2$ + cell size 1, 2, 3, 4 and 5, respectively), c (100 mg L–1 $Ca(NO_3)_2$ + cell size 1, 2, 3, 4 and 5, respectively), d (150 mg L–1 $Ca(NO_3)_2$ + cell size 1, 2, 3, 4 and 5, respectively) and e (the effect of different cell size1, 2, 3, 4 and 5 on height, respectively)

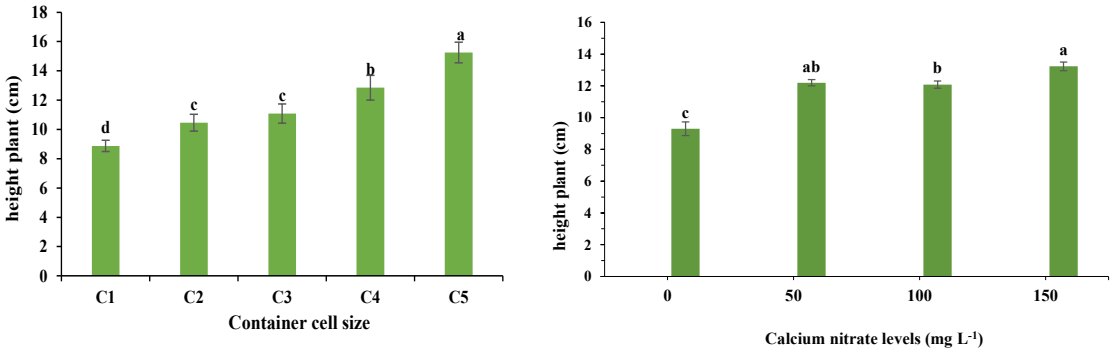

Fig. 2. The effect of cell size of transplant containers on plant height (a) and the effect of different levels of $Ca(NO_3)_2$ on height (b) of tomato transplants. C1, C2, C3, C4, and C5 refer to containers with 128, 96, 71, 45, and 24 cell numbers, respectively. Different letters indicate significant differences according to the LSD test $P < 0.05$

diameter, and number of leaves at $P \leq 0.01$. The results showed that the highest FW and DW of shoots and roots and the highest number of leaves and stem diameter were obtained with 150 mg L^{-1} $Ca(NO_3)_2$ × cell size 5. The significant increases in shoot FW and DW, root FW and DW, number of leaves, and stem diameter were 528%, 607%, 512%, 675%, 358%, and 88%, respectively, compared with the treatment without $Ca(NO_3)_2$ × cell size 1 (Tab. 3).

Photosynthetic pigments. The results revealed that Chl *a* and Chl *b* contents were significantly affected by different Ca $(NO_3)_2$ levels and container cell size at $P \leq 0.01$ (Tab. 4). Photosynthetic pigments increased with increasing the $Ca(NO_3)_2$ concentration and container cell size. The highest contents of Chl *a* (39.01 mg g^{-1} FW) and Chl *b* (26.49 mg g^{-1} FW) were achieved at 15 mg L^{-1} of Ca $(NO_3)_2$ × the cell size 5, which showed an increase of 93% and 96%, respectively, compared to the lowest content at the treatment without $Ca(NO_3)_2$ × cell size 1 (Tab. 4). The interaction of different levels of $Ca(NO_3)_2$ and container cell size had a significant effect on the carotenoid content of tomato seedlings at $P \leq 0.01$ (Tab. 4). The highest carotenoid content was obtained at 150 mg L^{-1} of $Ca(NO_3)_2$ and a cell size 5 (8.99 mg g^{-1} FW), which increased by 106% compared to the lowest measurement in the treatment without $Ca(NO_3)_2$ × cell size 1 (4.36 mg g^{-1} FW) (Tab. 4).

SPAD. According to the results, the effect of different $Ca(NO_3)_2$ concentrations and the container cell size was significant on the chlorophyll index (SPAD) at $P \leq 0.01$ (Tab. 4). The highest SPAD index (36.13) was found to be 150 mg L^{-1} of $Ca(NO_3)_2$ × cell size 5, about 40% higher than the lowest SPAD chlorophyll index in the treatment without $Ca(NO_3)_2$ × cell size 1 (73.73) (Tab. 4).

Total soluble protein content. The results showed that the content of tomato transplant protein was significantly affected by the $Ca(NO_3)_2$ interaction and the container cell size at $P \leq 0.01$ (Tab. 4). The total soluble protein content improved with increasing the calcium nitrate concentration and the container cell size. The highest protein content (0.4847 mg g^{-1} FW) was achieved at 150 mg L^{-1} of $Ca(NO_3)_2$ combined with a cell size 5, which showed an increase of more than 281% compared to the treatment without $Ca(NO_3)_2$ × cell size 1 (0.1273 mg g^{-1} FW) (Tab. 4).

Total carbohydrate content. The results determined that the interaction of different concentrations of $Ca(NO_3)_2$ and the container cell size was significant for the carbohydrate content of tomato transplants at $P \leq 0.01$ (Tab. 4): the increasing $Ca(NO_3)_2$ concentration and the container cell size enhanced carbohydrate content. The highest carbohydrate content (25.27 mg g^{-1} FW) was obtained at 15 mg l^{-1} of $Ca(NO_3)_2$ and the cell size 5, which showed an increase of 205% compared to the control. The lowest amount of carbohydrates was observed in $Ca(NO_3)_2$ and the cell size 1 (8.27 mg g^{-1} FW) (Tab. 4).

Macro- and micronutrient concentrations. The results also showed that the macro- and micro-nutrient content in tomato shoots was significantly affected by different $Ca(NO_3)_2$ concentrations and container cell size (Tab. 5). The highest content of N (3.9%), K (2.65%), Ca (18.04%), and Fe (0.872 mg g^{-1} DW) was obtained with 150 mg l^{-1} calcium nitrate application and cell size 5, which resulted in significant improvement of 225%, 682%, 22%, and 763%, respectively, compared to the contents without $Ca(NO_3)_2$ × cell size 1. The highest content of Zn (0.492 mg g^{-1} DW) and Mn (0.575 mg g^{-1} DW) was obtained with 100 mg L^{-1} of $Ca(NO_3)_2$ and cell size 5, resulting in 387% and 537% significant improvement, respectively, in comparison to no $Ca(NO_3)_2$ × cell size 1 (Tab. 5).

Results showed that the macro- and micro-nutrients of the roots were significantly affected by different concentrations of $Ca(NO_3)_2$ and the size of cells (Tab. 6). The most significant content of N (4.6%), K (3.45%), Ca (19.8%), and Fe (0.720 mg g^{-1} DW) was observed in 150 mg L^{-1} Ca $(NO_3)_2$ and cell size of 5, which increased significantly 91%, 267%, 26%, and 425%, respectively than without $Ca(NO_3)_2$ × cell size 1. Also, the highest amount of Zn (0.705 mg g^{-1} DW) and Mn (0.467 mg g^{-1} DW) was obtained by applying 100 mg L^{-1} of $Ca(NO_3)_2$, and the cell size 5, and the last was observed without $Ca(NO_3)_2$ and cell size 1, which showed 126% and 204% significant increase, respectively (Tab. 6).

Pearsons correlation matrix and relative expressions. Pearson's correlations analysis for the evaluated features of tomato plants under different cell size containers and calcium nitrate application are illustrated in Figure 3a. The results showed a significant positive correlation between height, stem diameter, leaf num-

Table 4. Effect of $Ca(NO_3)_2$ and different cell size containers on SPAD, photosynthetic pigments, total soluble protein, and total carbohydrate content of tomato transplants

Cell size model	$Ca(NO_3)_2$	SPAD	Chl a (mg g^{-1} FW)	Chl b (mg g^{-1} FW)	CARs (mg g^{-1} FW)	Protein (mg g^{-1} FW)	Carbohydrate (mg g^{-1} FW)
1	0	25.7 ±0.896 l	20.18 ±0.608 m	13.48 ±0.720 j	4.36 ±0.119 h	0.127 ±0.006 hi	8.27±0.955 m
	50	27.8 ±0.327 k	20.55 ±0.308 lm	13.86 ±0.818 ij	4.58 ±0.345 h	0.169 ±0.007 gi	11.76±0.828 l
	100	30.2 ±0.216 j	21.13 ±0.628 l	14.33 ±1.138 hj	4.67 ±0.330 gh	0.163 ±0.006 gi	16.67±0.207 j
	150	32.8 ±0.247 fh	21.29 ±0.659 l	13.72 ±0.737 ij	4.62 ±0.114 h	0.177 ±0.006 fh	18.19±0.463 i
2	0	30.8 ±0.613 ij	23.64 ±0.298 k	14.97 ±0.512 gi	5.06 ±0.239 fg	0.121 ±0.011 i	18.81±1.261 hi
	50	32.2 ±0.572 hi	24.15 ±0.743 k	15.32 ±0.496 fh	5.11 ±0.169 ef	0.181 ±0.005 fg	12.15±0.573 l
	100	33.2 ±0.779 eh	25.13 ±0.206 j	16.1 ±0.681 fg	5.44 ±0.094 ef	0.198 ±0.006 fg	16.5±0.610 j
	150	33.9 ±0.450 cg	26.96 ±0.600 i	16.64 ±0.565 ef	5.52 ±0.140 e	0.205 ±0.021 eg	21.72±1.113 ef
3	0	32.5 ±0.103 gh	27.56 ±0.834 i	17.96 ±0.577 de	6.06 ±0.141 d	0.209 ±0.016 eg	13.88±0.937 k
	50	33.4 ±0.858 dh	29.95 ±0.132 h	18.44 ±0.426 d	6.09 ±0.040 d	0.225 ±0.011 ef	16.01±0.376 j
	100	34.3 ±0.544 be	30.93 ±0.099 fg	19.97 ±0.438 c	6.55 ±0.040 c	0.251 ±0.008 de	20.57±0.505 fg
	150	35.3 ±0.602 ab	30.27 ±0.708 gh	20.18 ±0.495 c	6.70 ±0.163 c	0.284 ±0.015 d	24.01±0.798 bd
4	0	33.4 ±1.257 dh	30.9 ±0.164 fg	22.87 ±0.809 b	7.66 ±0.189 b	0.248 ±0.012 de	16.09±0.752 j
	50	34.0 ±0.464 bf	33.81 ±0.511 e	22.85 ±0.542 b	7.53 ±0.154 b	0.375 ±0.024 c	20.69±0.902 fg
	100	34.7 ±0.655 ad	37.11 ±0.377 b	23.4 ±0.492 b	7.80 ±0.139 b	0.435 ±0.040 b	23.74±0.795 cd
	150	35.3 ±0.572 ac	34.94 ±0.116 d	23.3 ±0.677 b	7.69 ±0.169 b	0.296 ±0.005 d	25.87±0.509 a
5	0	34.0 ±0.653 bf	31.3 ±0.197 f	22.2 ±0.602 b	7.41 ±0.297 b	0.382 ±0.008 c	19.86±0.826 gh
	50	34.5 ±0.822 be	35.96 ±0.096 c	23.11 ±1.190 b	7.59 ±0.439 b	0.409 ±0.028 bc	22.63±0.405 de
	100	35.2 ±0.589 ac	35.05 ±0.430 cd	22.34 ±0.482 b	7.45 ±0.135 b	0.434 ±0.030 b	24.14±0.586 bc
	150	36.1 ±0.732 a	39.01 ±0.158 a	26.49 ±0.722 a	8.99 ±0.272 a	0.485 ±0.001 a	25.27±0.471 ab
S.O.V.	df						
Cell size	4	39.76**	86.83**	15.66**	2.056**	0.048**	231.72**
$Ca(NO_3)_2$	3	60.94**	533.9**	284.9**	31.706	0.162**	129.31**
Cell size × $Ca(NO_3)_2$	12	3.670**	4.698**	2.552**	0.328	0.004**	4.66**
Error	40	0.721	0.318	0.708	0.067	0.023	0.824
C.V.		2.58	4.94	4.41	4.09	7.66	4.82

** significant at the 1% probability levels

Table 5. Effect of $Ca(NO_3)_2$ and different cell size containers on the shoot nutritional content of tomato transplants

Cell size model	$Ca(NO_3)_2$ (mg L^{-1})	N (%)	K (%)	Ca (mg g^{-1} DW)	Fe (mg g^{-1} DW)	Zn (mg g^{-1} DW)	Mn (mg g^{-1} DW)
1	0	1.2±0.125 i	0.339±0.177 l	14.74±1.025 i	0.101±0.303 k	0.101±0.042 i	0.0733±0.049 i
	50	2.2±0.254 f	0.415±0.122 kl	15.64± 0.987 ef	0.181±0.0909 j	0.164±0.034 g	0136±0.059 g
	100	2.4±0.241 e	0.772±0.154i	16.64±1.473 c	0.270±0.970 hi	0.309±0.016 c	0.281±0.036 c
	150	2.7±0.170 d	1.305±0.460f	14.54±0.941 ab	0.319±0.835 gh	0.210±0.023 f	0.182±0.039f
2	0	2.3±0.191 j	0.409±0.201kl	15.14±1.078 j	0.111±0.0012k	0.108±0.075 i	0.0806±0.087 i
	50	2.0±0.097 j	0.672±0.227ij	16.54±0.827 h	0.183±0.092 j	0.198±0.014f	0.170±0.011 f
	100	3.2±0.183 h	1.135±0.426g	17.44±0.718 e	0.359±0.0574 fg	0.482± 0.018 a	0.454±0.108 a
	150	3.7±0.138 d	1.689±0.619e	14.64±0.694 b	0.389±0.0602 ef	0.302±0.079 cd	0.274±0.157 cd
3	0	2.1±0.231 j	0.476±0.163k	15.14±0.921 j	0.134±0.027 k	0.108±0.019 i	0.080±0.105i
	50	2.8±0.346 h	0705±0.510ij	16.64±0.790 g	0.215±0.103 j	0.201±0.098 f	0.173±0.053 f
	100	2.6±0.418 h	1.255±0.426fg	17.44±1.057 d	0.404±0.072 rf	0.480±0.081a	0.452±0.092 a
	150	3.2±0.350 c	2.055±0.422c	14.84±1.108 ab	0.472±0.047 d	0.295±0.027 cd	0.267±0.101 cd
4	0	1.8±0.341 i	0.472±0.124k	15.04±0.587 i	0.214±0.026 j	0.108±0.015 i	0.080±0.096 i
	50	2.0±0.406 j	0.872±0.504h	16.84±0.734 f	0.349±0.058 fg	0.203±0.055 f	0.175±0.046 f
	100	2.7±0.492h	1.555±0.393e	17.54±1.117 cd	0.569±0.074 c	0.478±0.035 a	0.450±0.046 a
	150	3.3±0.193 b	2.355±0.530b	15.04±0.882 ab	0.646±0.166 b	0.288±0.012 d	0.260±0.076 d
5	0	2.2±0.109 h	0.572±0.308j	15.54±0.919 g	0.227±0.048 ij	0.128±0.018 h	0.100±0.025 h
	50	2.4±0.117 f	0.972±0.481h	17.14±0.579 e	0.427±0.046 de	0.248±0.014 e	0.220±0.048 e
	100	2.8±0.327 d	1.855±0.337d	18.04±0.264 b	0.663±0.084 b	0.492± 0.015 a	0.467±0.052 a
	150	3.9±0.307 a	2.655±0.640a	18.95±0.332 a	0.872±0.091 a	0.332±0.185 b	0.304±0.034b
S.O.V.	df						
Cell size	4	2.181^{**}	2.612^{**}	1.342^{**}	0.197^{*}	0.024^{*}	0.268^{**}
$Ca(NO_3)_2$	3	1.798^{**}	5.687^{*}	9.287^{**}	0.436^{**}	0.161^{*}	0.002^{**}
Cell size × $Ca(NO_3)_2$	12	0.012^{*}	0.306^{**}	0.120^{**}	0.007^{**}	0.002^{**}	0.001^{*}
Error	40	0.002	0.006	0.007	0.004	0.010	0.006
C.V.		6.70	7.62	8.25	8.15	4.50	8.01

Table 6. Effect of $Ca(NO_3)_2$ and different cell size containers on the root nutritional content of tomato transplants

Cell size model	$Ca(NO_3)_2$ (mg L^{-1})	N (%)	K (%)	Ca(mg g^{-1} DW)	Fe (mg g^{-1} DW)	Zn (mg g^{-1} DW)	Mn (mg g^{-1} DW)
1	0	2.4 ±0.208 j	0.939 ±0.028 l	15.6 ±0.025 k	0.166 ±0.002 h	0.311 ±0.049 i	0.189 ±0.049 j
	50	2.8 ±0.119 i	1.116 ±0.041 k	16.5 ±0.060 hi	0.296 ±0.027 g	0.374 ±0.060 g	0.244 ±0.034 h
	100	3.4 ±0.371 e	1.572 ±0.507 i	17.4 ±0.437 f	0.528 ±0.073 ef	0.519 ±0.083 c	0.390 ±0.036 d
	150	3.7 ±0.480 d	2.105 ±0.131 f	18.4 ±0.010 e	0.600 ±0.047 de	0.420 ±0.075 f	0.290 ±0.043 g
2	0	3.3 ±0.109 e	0.705 ±0.086 m	16.3 ±0.338 j	0.0983 ±0.002 h	0.318 ±0.108 i	0.189 ±0.004 j
	50	2.8 ±0.093 h	1.505 ±0.136 ij	16.9 ±0.080 g	0.298 ±0.042 g	0.408 ±0.080 f	0.280 ±0.093 g
	100	3.6 ±0.173 de	1.935 ±0.454 gh	18.3 ±0.226 e	0.474 ±0.067 f	0.692 ±0.127 a	0.562 ±0.081 ab
	150	4.1 ±0.314 c	2.489 ±0.224 e	19.1 ±0.227 b	0.684 ±0.096 c	0.512 ±0.120 cd	0.382 ±0.096 de
3	0	2.5 ±0.122 i	0.772 ±0.041 m	16.4 ±0.155 ij	0.159 ±0.005 h	0.318 ±0.152 i	0.189 ±0.022 j
	50	3.8 ±0.604 d	1.172 ±0.070 k	16.9 ±0.125 g	0.330 ±0.052 g	0.411 ±0.102 f	0.281 ±0.041 g
	100	3.6 ±0.241 de	2.05 ±0.412 fg	18.4 ±0.082 e	0.566 ±0.048 e	0.690 ±0.128 a	0.560 ±0.034 ab
	150	4.2 ±0.113 c	2.855 ±0.389 cd	19.2 ± 0.119 b	0.660 ±0.059 cd	0.505 ±0.075 cd	0.375 ±0.050 de
4	0	2.8 ±0.309 i	1.072 ±0.081 kl	16.6 ±0.136 h	0.329 ±0.026 g	0.318 ±0.103 i	0.208 ±0.022 i
	50	3.0 ±0.718 g	1.472 ±0.070 ij	16.8 ±0.222 gh	0.531 ±0.058 ef	0.413 ±0.119 f	0.283 ±0.062 g
	100	3.7 ±0.621d	2.355 ±0.476 e	18.6 ±0.287 cd	0.767 ±0.085 b	0.688 ±0.096 a	0.558 ±0.096 a
	150	4.3 ±0.176 bc	3.155 ±0.205 b	19.3 ±0.307 b	0.861 ±0.047 a	0.498 ±0.046 d	0.368 ±0.098 d
5	0	2.8 ±0.203 h	1.372 ±0.081 j	16.8 ± 0.098gh	0.342 ±0.023 g	0.338 ±0.059 h	0.208 ±0.059 h
	50	3.2 ±0.402 ef	1.772 ±0.070h	17.3 ±0.116 f	0.542 ±0.066 ef	0.458 ±0.007 e	0.328 ±0.079 e
	100	3.7 ±0.419 d	2.655 ±0.379 d	18.9 ±0.321 bc	0.778 ±0.068 b	0.705 ±0.094 a	0.575 ±0.080 a
	150	4.6 ± 0.116 a	3.455 ±0.277 a	19.8 ± 0.256 a	0.872 ±0.098 a	0.542 ±0.098 b	0.412 ±0.087b
S.O.V.	df						
Cell size	4	3.197^{**}	1.404^{*}	1.197^{**}	0.192^{*}	0.069^{*}	0.214^{**}
$Ca(NO_3)_2$	3	2.436^{*}	9.796^{**}	2.436^{*}	0.764^{**}	0.178^{**}	0.010^{**}
Cell size × $Ca(NO_3)_2$	12	0.017^{**}	0.129^{**}	0.007^{**}	0.002^{*}	0.006^{*}	0.012^{**}
Error	40	0.011	0.007	0.001	0.005	0.003	0.002
C.V.		7.13	6.16	8.17	7.55	5.38	4.96

* and ** significant at the 5% and 1% probability levels, respectively

ber, fresh and dry weight of root and shoot, root and shoot K and Fe, carbohydrate content, photosynthesis pigments, protein content, and SPAD. Also, the photosynthesis pigments had a considerable positive correlation with the concentration of Cu, Zn, Fe, and K of shoots and roots.

The heat map of clusters in traits and treatments showed several different groups, as presented in Figure 3b. So, the assessed traits were placed in four clusters. Cluster 1 included the concentration of K and Fe of shoot and root, as well as protein. Cluster 2 comprised Cu, Zn, and Mn concentrations of shoot and root, as well as photosynthesis pigments. Also, carbohydrate content, stem diameter, and SPAD were in cluster 3, and finally, fresh and dry weight of shoot and root, leaf number, and height were placed in cluster 4. Also, Cluster pattern and heat map analysis revealed four main clusters in $Ca(NO_3)_2$ and different cell-size containers. Cluster 1 contained the plants treated with the highest $Ca(NO_3)_2$ along with cell size containers of 2, 3, 4, and 5, as well as the tomato transplants were grown under 100 mg L^{-1} of $Ca(NO_3)_2$ application in a container with cell size 4, finally, the plants treated with 50 and 100 mg L^{-1} in containers with a cell size of 5. Cluster 2 included the tomato plants grown in cell sizes 1 and 2 with no $Ca(NO_3)_2$ application. Cluster 3 contained the application of 100 mg L^{-1} of $Ca(NO_3)_2$ along with cell size containers 1, 2, and 3, as well as 150 mg L^{-1} of $Ca(NO_3)_2$ in cell size 1. Finally, cluster 4 comprised all the container cell sizes along with 50 mg L^{-1} of $Ca(NO_3)_2$ and the container cell sizes 3, 4, and 5 with no $Ca(NO_3)_2$ application.

DISCUSSION

In the current study, applying different calcium nitrate concentrations and container cell sizes significantly increased the plant height of tomato transplants. N is abundant in plant tissues, and nucleotides and enzymes are necessary for developing the plant structure. Therefore, it can significantly increase plant growth by improving chlorophyll content and synthesizing amino acids to produce essential proteins [Coskun et al. 2017]. N is also involved in the formation of many plant organic compounds and its effect on plant growth due to its positive effects on photosynthetic activity and metabolic processes of organic compounds in the plant, thus enhancing vegetative growth and plant height [El Gendy et al. 2015]. In addition, plants in well-sized pots and containers exhibit better growth characteristics, including vegetative growth, leaf area size, and broad roots, than plants in smaller containers [Yang et al. 2010]. Larger containers promote plant growth by increasing nutrient availability for metabolism and root development. In addition, greater water retention capacity leads to better aerial growth. In this regard, Oviedo and Minami [2012] reported that the cell size of containers significantly increased the height of tomato transplants. On the other hand, it was reported an increase in the height of the bean plant (*Phaseolus vulgaris* L.) and wheat (*Triticum aestivum* L.) with the use of N, which was consistent with our results [Salehin and Rahman 2012, Hassanein et al. 2018]. Adding Ca^{2+} through fertilization is a highly effective approach in enhancing the growth and yield of maize by ensuring the maintenance of turgor [Naeem et al. 2018]. Ca is an essential nutrient in binding polysaccharides and proteins that make up the cell wall and helps auxin activity in cell division and elongation [Marschner 2012]. Ca also increases plant growth by increasing meiotic activity in the terminal meristem. According to these results, an increase in the height was reported in tomato [Rab and Haq 2012] and peanut (*Arachis hypogaea* L.) [Kabir et al. 2013] plants treated with Ca nitrate fertilizer.

The results of this study demonstrated that the different concentrations of calcium nitrate combined with the different container cell sizes significantly increased certain growth traits of tomato transplants. The treatments improved root growth through root stimulation, increased photosynthetic products, and high water and nutrient uptake, consequently leading to increased stem diameter and number of leaves [Liu et al. 2020]. These fertilizers enhance the growth performance of plants by providing nutrients at different stages of growth. On the other hand, Ca, as an essential element in plants, plays various roles, including structural functions in cell walls and cell membrane stabilization, and contributes to many physiological and biochemical activities of plants, such as plant growth, cell division, cytoplasmic flow, and photosynthesis [Huang et al. 2017]. Similar results were reported regarding the positive effect of calcium nitrate on the growth traits of tomato [Gülser 2005], spinach, and German chamomile [Boroujerdnia and Ansari 2007],

with significantly increased leaf area, number of leaves, fresh and dry weights of roots and shoots, and yield. Hamdi et al. [2015] reported that height, stem diameter, and number of lateral stems increased using N in potato plants. The increase in the fresh and dry weights of roots and shoots by the N application is due to its vital role in compounds such as amino acids, nucleic acids, ribosomes, and proteins, as well as a vital component of chlorophylls, rubisco molecules, and greenness growth of the plant [Gul and Whalen 2016].

In addition, it is crucial to select the appropriate culture medium size for each crop based on the growth rate, final size, and growth conditions. Improved plant growth due to increasing the size of the culture medium (containers and pots) can be attributed to soil physical properties, such as ventilation and drainage, which increase nutrient solubility and absorption and retain soil moisture [Boodia et al. 2011]. In this regard, Annapurna et al. [2004] found that the container cell size improved growth traits such as height, branch dry weight, and root dry weight in *Santalum album* L. It was also reported that increasing soil volume and nutrient content could increase plant growth traits such as fresh and dry weight, root-to-shoot ratio, stem diameter, and root length [Salisu et al. 2018].

The chlorophyll content is essential for understanding the plant's response to environmental conditions. Based on the results of the present study, different concentrations of calcium nitrate combined with the size of cells had a more significant effect on increasing the chlorophyll index (SPAD) and photosynthetic pigments of tomato plants. The application of Ca as a foliar spray resulted in enhanced growth and an increase in the content of photosynthetic pigments [Valivand and Amooaghaie 2021]. The addition of Ca has been shown to enhance gas exchange characteristics significantly. Thus, it can be attributed to Ca's favorable role in maintaining the photosynthetic apparatus [Naeem et al. 2018]. It indicates a synergistic effect of both treatments on the traits evaluated. In general, studies have shown that increasing the size of containers has a positive impact on the biomass of plant transplants. This is because larger containers provide more space for the roots to grow, allowing for increased nutrient uptake and overall plant growth. In addition, the size of the culture medium positively affects the growth traits and development of plant roots, nutrient uptake, and various properties related to photosynthetic production, stomatal conductance, transpiration rate, increased leaf CO_2 emission, and increased Rubisco activity, ultimately improving shoot size, number of leaves, and the chlorophyll index [Kasai et al. 2012]. Similar to this study, Khonghintaisong et al. [2018] also reported an increase in photosynthetic pigments by increasing the cell size of containers in sugarcane. On the other hand, the increase of leaf chlorophyll under calcium nitrate treatment is attributed to the role of nitrogen in plant metabolism and the modification of plant hormone balance that occurs in vegetative parts. Nitrogen is a crucial component of various biological molecules, such as amino acids, enzymes, coenzymes, and nucleic acids. Additionally, it plays an essential role in the structure of chlorophylls, which are the most critical photosynthetic pigments [Dubey et al. 2021]. Increasing the concentration of N in plants improves the content of ammonium and glutamate synthetase, the latter of which is involved in chlorophyll production, thereby improving chlorophyll content [Hasegawa et al. 2008]. In this regard, Roy et al. [2019] reported that the use of calcium improved the concentrations of Chl *a*, Chl *b*, carotenoids, and chlorophyll index in corn, and these improvements were due to an increase in branch length, root length, and biomass of roots and shoots. The findings suggest that calcium played a crucial role in the photosynthesis process by contributing to the potential active center of PSII, photochemical efficiency, photosynthetic electron transfer, and gene expression of chlorophyll synthesis-related enzymes in cucumber seedlings [Zhang et al. 2020]. An increase in leaf chlorophyll content was also reported with the application of calcium nitrate in rice [Xiong et al. 2015] and corn [Wu et al. 2019].

The total soluble protein of transplanted tomato leaves increased with increasing calcium nitrate fertilizer and the container cell size. Nitrogen fertilizers likely increase the amount of nitrogen imported to leaves compared to carbohydrates and improve nitrogen concentration and protein percentage [Kizito et al. 2019]. Consistent with these results, Ibrahim et al. [2018] showed that the application of nitrogen significantly increased the protein content in wheat compared to the control. Aminifard et al. [2012] observed that applying nitrogen fertilizer significantly improved

the leaf protein content of red pepper (*Capsicum annum* L.). In addition, calcium has a significant effect on increasing the protein content of tomato transplants. Calcium nitrate is plants' primary source of inorganic nitrogen, which controls nutrient transfer and adaptive growth response throughout the plant. In addition to being a significant nutrient, nitrate acts as a signaling molecule and can control nutrient uptake, morphological and physiological responses, and the root system [Fredes et al. 2019]. The results of this study are consistent with those of Kamara et al. [2017] peanut. Our results also showed that the highest amount of leaf protein was obtained in the container with larger cell sizes. It has been reported that leaf protein content increases in the plant by increasing the pot size and container cells. Moreover, the availability of sufficient nutrients in the roots with increasing the size of the culture medium has been proven to increase root biomass and thus improve the protein content by expanding the plant's aerial [Obede da Silva Aragão et al. 2020]. Thus, it can be concluded that the size of the culture medium has a positive effect and improves leaf protein content. Increasing the size of containers can increase protein synthesis through the uptake of active ions and some biochemical mechanisms, which may be another reason for the increase in protein content in the present study [Salisu et al. 2018].

Changes in total soluble carbohydrate content are of particular importance due to their direct relationship with physiological pathways, such as photosynthesis, respiration, and transport. The content of carbohydrates treated with calcium nitrate and the size of container cells were significant at different stages of growth in comparison with control plants. Nitrogen is an essential mineral nutrient vital to crop growth, productivity, and quality. This element is involved in the production of protein and leaf surface chlorophyll; thus, it is necessary for cell division, the formation of new cells, and, as a result, plant growth and development. With higher nitrogen consumption, carbon sequestration increases in plants, which increases the number of soluble carbohydrates in plants [Mekdad 2015]. Our results are consistent with those reported in potato [Meise et al. 2018] and sugar beet [Mekdad 2015] plants. They reported that nitrogen application at different stages of plant growth improved growth traits and positively affected the amount of carbohydrates in leaves and tubers. The results also indicate that calcium increased the amount of leaf carbohydrates in the present study compared to the control. Calcium has increased leaf carbohydrate content by increasing morphological and photosynthetic traits in the plant, which can be attributed to applying calcium to the soil. More calcium in the shoots enhances the number of leaves and lateral branches and improves leaf carbohydrates [Kumar et al. 2007]. In this regard, an increase in carbohydrate content was observed in the potato plant by soil application of calcium [Abbasi et al. 2012]. On the other hand, the improvement in leaf carbohydrates with increasing the cell size of containers may be due to the improved growth activity, the availability of more water, better rooting, and thus improvements in nutrient storage capacity and biomass [Poorter et al. 2012]. The most desirable amount of plant carbohydrates was observed with a larger cell size. These cells are likely to provide a suitable environment for water and plant nutrients. The amount of carbohydrates in these systems increased due to the high concentrations of calcium and nitrogen in the culture medium. In a study using different culture media on nutrient uptake in the *P. vulgaris* species, increasing the cell size significantly affected root biomass activity and improved nutrient uptake [Obede da Silva Aragão et al. 2020].

Based on the results of this study, the highest nutrient concentrations were obtained in containers with larger cell sizes and calcium nitrate application. Nitrogen is one of the primary nutrients used more than other elements in plants [Albornoz 2016]. Our results were consistent with red pepper [Ortas 2013] and tomato plants [Djidonou et al. 2019]. They reported that the addition of nitrogen at different stages improves the growth characteristics, increases biomass activity, and ultimately leads to better absorption of nutrients such as N, P, and K in the plant. Ca fertilizers are crucial for maintaining K homeostasis in plant cells, resulting in a rise in cytosolic K concentration [Nasrallah et al. 2022]. Activation of calcium-sensitive protein channels in the root zone increases nutrient availability, promoting greater root penetration [Fellet et al. 2021]. According to a recent study, the concentration of macro-nutrients such as N, K, and Ca, as well as micro-nutrients like Fe, Zn, and Mn, in maize grains was found to be significantly enhanced by the

application of calcium through foliar supply, which indicates that calcium has a synergistic effect on the uptake and translocation of these nutrients [Naeem et al. 2018]. Xiao-long et al. [2018] reported that the use of different levels of calcium increased nutrient uptake (N, P, K, Ca) in peanuts.

In addition, increasing the content of nutrients in containers with larger cell sizes can be due to improved water and nutrient supply and root placement in more soil volume, and therefore, may lead to better ventilation, drainage, improvement of absorption, and storage of soil moisture [Boodia et al. 2011]. The effect of different culture media on the nutrient content in tomatoes showed that the highest concentration of nitrogen was obtained by increasing root growth, which, due to its high cation exchange capacity, increased the uptake of nutrients, especially nitrogen [Borgognone et al. 2013]. Consistent with our results reported in maize [Oliveira et al. 2010]. Larger culture media size can increase nutrients such as N, P, K, Ca, and Mg and improve root biomass and plant growth traits. Calcium not only serves as a nutrient but also acts as a second messenger in signaling nutrient availability and changes. *CIPK23* regulates the uptake of K+ and the activity of *IRT1* in *Arabidopsis* plants via the Ca decoding complex consisting of *CBL1/9*. *IRT1* transports iron and other minerals, such as zinc and manganese [Alrashidi et al. 2022]. The reason for the enhancement in the concentration of nutrients can be attributed to the increase in soil and water available to the roots because increasing the culture medium reduces the limit of root growth and leads to more nutrient uptake [Megersa et al. 2018].

CONCLUSIONS

Tomato transplant production is most important in tomato growing and significantly affects final yield and quality. Then, the quality of the transplanted plants should be improved by changing and improving the environmental and nutritional conditions. Our results showed that applying Ca(NO3)2 and enhancing container cell size improved the evaluated traits, such as plant growth physiological or biochemical and nutritional characteristics. We conclude that cell sizes 5, 100, and 150 mg l–1 had the best efficiency in tomato transplant production. However, the best cell size will be determined according to the cost of planting containers, the number of transplants required, and availability in the market..

AUTHOR CONTRIBUTIONS

Conceptualization, formal analysis, investigation, resources, data curation, methodology, and software, M.A., T.A.; writing – original draft preparation, F.R., S.G.; writing – review and editing, N.S., S.E., A.A., L.S. J.M. SOURCE OF FUNDING
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Institutional Review Board Statement. Ethics approval and consent to participate. The plant material (seeds) complied with some relevant national and international guidelines and legislation.

INFORMED CONSENT STATEMENT. Not applicable.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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