Eco. Env. & Cons. 29 (April Suppl. Issue) : 2023; pp. (S378-S385)

ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2023.v29i02s.061

Seed priming with $Mg(NO_3)_2$ and $Ca(NO_3)_2$ salts influence the growth of tomato seedlings

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(Received 13 October, 2022; Accepted 23 December, 2022)

ABSTRACT

Seed is the most valuable input in agriculture, and high-quality seeds are required for healthy crop production. Various seed quality enhancement technologies are continuously used for better establishment of crop in field. Seed priming is one of the best, cheapest, reliable and cost-effective strategies to boost seed germination and seedling establishment. This experiment was conducted to determine the effect of seed priming with various concentration of $Mg(NO_3)_2$, and $Ca(NO_3)_2$ salts in two tomato genotypes (VRT 06 and Punjab Chhuhara) on germination and seedling growth. The concentration level C0 to C7 (2.5 mM to 20 mM) were used for priming purpose and germination parameters were recorded. From the study of germination %, mean germination time (MGT)(days), Germination index (GI), Coefficient of velocity of germination (CVG) and Germination rate index (GRI) (%/day), seedling length (cm), seedling fresh weight (FW) (mg), seedling dry weight (DW) (mg) and seedling vigor index (SVI), it was revealed that 7.5mM of $Mg(NO_3)_2$, and $Ca(NO_3)_2$, were the most effective treatments, which were able to improve performance of seedling establishment of tomato seeds.

Key words: *Germination %, Mean germination time, Seed priming, Seedling vigor*

Introduction

Tomato (*Lycopersicon esculentum* Mill.) is an important and popular vegetable fruit growing worldwide. It belongs to the family Solanaceae and is a self-pollinated crop with 2n=24 chromosome number (Salim *et al.,* 2020). It is used as either fresh or processed food (Nowicki *et al.,* 2013). Several types of cultivated tomato provide evidence that the tomato was originally domesticated in Mexico (Jenkins, 1948; Rick *et al.,* 1974). Due to increasing demand of tomato, it is important to increase production of per unit area. To fulfill this demand, scientists developed improved genotypes of crops and use other various technologies. Seed priming is one of the reliable, eco-friendly, and cheapest strategies for improving seedling establishment of crop, that helps to enhance the productivity, quality and nutritious value of crops (Tamta and Singh, 2018; Bose *et al.,* 2018; Chakraborty and Dwivedi, 2021).

Seed priming with $Mg(NO_3)_2$ significantly increases in germination percent, seedling length, seedling vigor index (SVI), and other germination parameters such as mean germination time (MGT), gemination index (GI), Coefficient of Velocity of Germination (CVG), and Germination Rate Index (GRI) of crop (Singhal and Bose, 2020; Choudhary *et al.,* 2021). Calcium is an important plant nutrient and being a part of the cell wall structure and cell elongation. It performs an important role for cell division, regulation of nutrients uptake across the membranes and also improves water uptake of crops

(Ibrahim, 2016). $Ca(NO_3)_2$ seed priming of crops potentiates the germination process, resulting in increase germination and radicle emergence rates (Salles *et al.,* 2019). It also improves speed of germination, length of seedling, fresh and dry biomass of seedling and allows a greater expression of seed vigor in various crops (Barbosa *et al.,* 2016; Gouveia *et al.,* 2017; Maneesha, 2019).

Hence, in the present investigation, seeds of tomato (*Lycopersicon esculentum* Mill.) genotypes VRT 06 and Punjab chhuhara were taken to find out the effect of seed priming with various concentration of $Mg(NO_3)_2$ and $Ca(NO_3)_2$ salts on germination and seedling growth of the tomato crop.

Materials and Methods

Seeds of two tomato genotypes VRT 06 and Punjab chhuhara were used as plant materials for the present experiments. Both genotypes were obtained from Indian Institute of Vegetable Research (IIVR), Varanasi, Uttar Pradesh. The experiment was conducted in the Department of Plant Physiology, Institute of Agricultural Sciences, Banaras Hindu University, Varanasi, India. Healthy tomato seeds were selected and sterilized with 0.1% HgCl—$_2$ solution, and then all the seeds were washed with distilled water. After sterilization seeds were soaked in various concentrations of Mg $(NO_3)_2$ (S1) and $Ca(NO_3)_2$ (S2) and distilled water for hydropriming. The solution concentration was 2.5 mM (C2), 5 mM (C3), 7.5 mM (C4). 10 mM (C5), 15 mM (C6) and 20 mM (C7), while nonprimed seeds and hydro-primed seeds were represented by C0 and C1, respectively. After 24 hours of soaking, seeds were kept out from solution and put on clean tissue paper to remove moisture from the surface of the seeds, and dried all seeds properly in natural condition. All seeds were dried until they reached a pre moisture level, which was confirmed by weight.

After drying seeds were taken for germination studies and placed in pre-sterilized petri-plates containing germination paper. 5 ml of distilled water was poured in each petri-plates. All petri-plate were placed at normal room temperature. Germination and seedling parameters were noted up to 7 days in laboratory condition. The experiment was conducted in Completely Randomized Design (CRD) with three replications.

The observation of germination % was taken at 24h, 48h, 72h, 96h, 120h, 144h, and 168h and calculated using the following formula-

$$\text{Germination\%} = \frac{\text{Total number of seed germinated}}{\text{Total number of seed sown}} \times 100$$

At 7 days of germination, seedling parameters including seedling length, fresh and dry weight, and seedling vigor data were taking using conventional methods. Other germination parameters such as mean germination time (MGT), germination index (GI), germination rate index (GRI), and coefficient of velocity of germination (CVG) were calculating by using following formula:

Seedling vigour index (SVI): Seedling vigour index measured in 7-day old seedling by the formula given by Goodi and Sharifzadeh (2006).

SVI = germination % × seedling length

Mean germination time: Mean germination time calculated by the formula given by Al-Mudaris (1998).

MTG (in days) = $\Sigma F^*x/\Sigma F$

where, F is the number of seed germinated on day x

Germination index (GI): Germination index of tomato seed calculated by the formula given by Ranal *et al.* (2009).

$$GI = (4\times N1) + (3\times N2) + \cdots + (1\times N4)$$

where, N1, N2, ... N4 is the number of germinated seeds on the first, second and subsequent days until final germination day.

Germination Rate Index (GRI): GRI calculated by the formula given by the Al-Mudaris (1998).

GRI = G1/1 + G2/2 +· · ·+ Gx/x

where G1 is the germination percentage on day 1, G2 is the germination parentage on day 2; and so on.

Coefficient of Velocity of Germination (CVG): CVG calculated by the formula given by Al-Mudaris (1998).

CVG = N1 + N2 + · · + Nx/100 × N1T1 + · · · + NxTx

N = Number of seeds germinated each day, T=Number of days from seeding corresponding to N

Mean value from three replication of each treatment was taken in presented table. Analysis of variance was performed using SPSS version 16.0 software. Duncan's test was performed to determine significant differences among treatments.

Results

Germination Percent (%)

Germination percent reveals the capacity of plant to germinate. The germination percentage was recorded at 24, 48, 72, 96, 120, 144 and 168h in both genotypes of tomato, namely VRT 06 and Punjab Chhuhara, primed with various concentration (C0 to C7) of salts. C0 represents non-primed, C1 hydro-primed (Water primed without salts), C2 (2.5mM), C3 (5mM), C4 (7.5mM), C5 (10mM), C6 (15mM), and C7 represents (20mM). The germination percent increased with times in all used salts (Table 1). The higher mean germination percent was recorded in S1C4 at all time periods in both genotypes. The germination percentage in V1 was 16.67%, 33.33%, 66.67%, 83.33%, 93.33%, 96.67%, 96.67%, and in V2 was 16.67%, 30%, 63.33%, 83.33%, 90%, 96.67%, 96.67%S, recorded at 24h, 48h, 72h, 96h, 120h, 144h, and 168h, respectively. S1C4 was followed by S1C1 at all time periods in both verities but at 168h S1C4 was similar with S1C1 in case of V2. High and low $Mg(NO_3)_2$ concentration and control showed lower germination percentage at all respective periods in both the genotypes.

Table 2 represent the germination percent of $Ca(NO_3)_2$ primed seed (S2) with different concentrations i.e. C0 (non-primed), C1 hydro-primed (Water primed without salts), C2 (2.5mM), C3 (5mM), C4 (7.5mM), C5 (10mM), C6 (15mM), and C7 (20mM) recorded at 24, 48, 72, 96, 120, 144 and 168h in both genotypes of tomato namely VRT 06 (V1) and Punjab Chhuhara (V2). In this case, S2C4 always showed highest germination % in both genotypes at all time periods, i.e. 24h to 168h. The germination % of S2C4 in V1 was 16.67%, 33.33%, 73.33%, 83.33%, 93.33%, 96.67% and 96.67%, while germination % in V2 for S2C4 was 16.67%, 33.33%, 70%, 80% 93.33%, 96.67% and 96.67%, recorded at 24h, 48h, 72h, 96h, 120h, 144h, and 168h time periods. At 144 and 168 h S2C4 showed similar germination % in V2, means there is no change. In case of V2, S2C1 and S2C4 showed similar germination % at 168h, followed by S2C2, S2C3, and S2C5 treatment, i.e. 86.67% and lowest germination % was observed in S2C7 (20mM $Ca(NO_3)_2$) with 73.33%. In V1 S2C4 (96.67%) is followed by S2C1 (93.33%), and lowest was observed in S2C6 and S2C7 (i.e., 76.67%) at 168h.

Mean germination time (MGT) (days), Germination index (GI), Coefficient of velocity of germina-

Table 1. Effect of seed priming with different concentrations of $Mg(NO_3)_2$ salts on the germination percentage (%) of two selected tomato varieties at different study periods of germination.

Treatment	GERMINATION PERCENTAGE (%)													
	24h		48h		72h		96h		120h		144h		168h	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
S1C0	10.00±0.00ab	6.67±5.77b	26.67±5.77abc	20.00±0.00b	53.33±5.77bc	50±0b	63.33±5.77b	60±0de	80.00±0.00b	76.67±5.77bcd	86.67±5.77abc	83.33±5.77bc	86.67±5.77abc	83.33±5.77b
S1C1	16.67±5.77a	13.33±5.77ab	30.00±0.00ab	26.67±5.77ab	63.33±5.77ab	60±0a	80.00±0.00a	76.67±5.77ab	86.67±5.77ab	83.33±5.77ab	93.33±5.77ab	93.33±5.77ab	93.33±5.77ab	96.67±5.77a
S1C2	6.67±5.77b	6.67±5.77b	23.33±5.77bc	20.00±0.00b	36.67±5.77d	36.67±5.77cd	53.33±5.77c	50±0f	76.67±5.77b	73.33±5.77cd	86.67±5.77abc	83.33±5.77bc	86.67±5.77abc	83.33±5.77b
S1C3	6.67±5.77b	10±0ab	26.67±5.77abc	23.33±5.77b	40.00±10d	43.33±5.77bc	53.33±5.77c	53.33±5.77ef	83.33±5.77ab	83.33±5.77ab	86.67±5.77abc	90±0abc	86.67±5.77abc	90±0ab
S1C4	16.67±5.77a	16.67±5.77a	33.33±5.77a	30.00±0.00a	66.67±5.77a	63.33±5.77a	83.33±5.77a	83.33±5.77a	93.33±5.77a	90±0a	96.67±5.77a	96.67±5.77a	96.67±5.77a	96.67±5.77a
S1C5	10.00±0.00ab	13.33±5.77ab	23.33±5.77bc	23.33±5.77b	43.33±5.77cd	43.33±5.77bc	70.00±0.00b	70±0bc	83.33±5.77ab	83.33±5.77ab	90.00±10.0abc	90±10abc	90.00±10abc	90±10ab
S1C6	13.33±5.77ab	13.33±5.77ab	20.00±0.00c	20.00±0.00b	43.33±5.77cd	40±0cd	66.67±5.77b	66.67±5.77cd	83.33±5.77ab	80±0bc	83.33±5.77bc	86.67±5.77abc	83.33±5.77bc	90±0ab
S1C7	13.33±5.77ab	10.00±0.00ab	23.33±5.77bc	20.00±0.00b	36.67±5.77d	33.33±5.77d	53.33±5.77c	50±0f	76.67±5.77b	70±0d	80.00±0.00c	80±0c	80.00±0.00c	80±0b
SEm±	1.021	1.021	1.021	.722	1.318	.932	1.021	.833	1.102	.932	1.250	1.179	1.250	1.102
	P Value		P Value		P Value		P Value		P Value		P Value		P Value	
V	NS		*		NS		NS		NS		NS		NS	
T	*		**		**		**		**		**		**	
VxT	NS		NS		NS		NS		NS		NS		NS	

Variety : V1= VRT 06, V2= Punjab Chhuhara,
Salt : S1= $Mg(NO_3)_2$,
Concentration: C0= Control, C1= Hydra Priming, C2= 2.5mM,C3= 5mM, C4=7.5mM, C5= 10mM, C6= 15mM, C7=20mM
Data represent means of three replicates. Values with same letters are not significantly different at p≤0.05 according to DMRT post hoc test. *indicate significant level at p≤0.05 and ** indicate significant level at p≤0.01

tion (CVG) and Germination rate index (GRI) (%/day):

Mean germination time (MGT) is an important trait to measure the speed of germination. Lower value of MGT denotes the higher speed of germination. Table 3 represents mean germination time (MGT) of seeds, germination index (GI),coefficient of velocity of germination (CVG) and germination rate index (GRI) (%/day) of tomato genotypes VRT 06 (V1) and Punjab chhuhara (V2), which were primed with various concentrations (C0 to C7) of $Mg(NO_3)_2$. S1C4 (7.5mM) treatment lowered MGT value among the treatment in both genotypes, which was 2.96 and 3.06 in V1 and V2, respectively, while highest value was observed in S1C2 (2.5mM primed seed) in V1 (3.72) and V2 (3.76). The data also revealed the value of germination index of both genotypes of tomato, primed with different concentrations of $Mg(NO_3)_{2-}$. The highest germination index was observed in S1C4 (7.5mM $Mg(NO_3)_2$) which was 155.33 and 150.67 in V1 and V2, respectively. S1C4 was followed by S1C1 (hydro-primed), and the lowest value of germination index was 100.67 observed in S1C7 (20mM $Mg(NO_3)_2$ primed seed) treatment of V2, and the lowest value of germination index in V1 was 107.33 which was observed in S1C2 (2.5mM $Mg(NO_3)_2$). Highest CVG value was observed in S1C4 (7.5mM $Mg(NO_3)_{2-}$), which was 33.79 and 32.71 in V1 and V2, respectively. The lowest value was observed in S1C2 (2.5mM $Mg(NO_3)_{2-}$), which was 26.95 and 26.66 in V1 and V2, respectively. GRI data of $Mg(NO_3)_2$ primed seeds revealed that the lowest GRI value was observed in S1C2 in both genotypes, which was 29.94 and 28.55 in V1 and V2, respectively. While the highest GRI value was recorded in S1C4, which was 42.83 and 41.89 in genotypes V1 and V2, respectively.

Table 4 represents mean germination time (MGT) of seeds, germination index (GI), coefficient of velocity of germination (CVG) and germination rate index (GRI) (%/day) of tomato genotypes VRT 06 (V1) and Punjab chhuhara(V2), primed with various concentrations (C0 to C7) of $Ca(NO_3)_2$. The lowest MGT value in V1 was observed in S2C4 (2.89), while in V2 it was observed in S2C7 (20mM), which was 2.82 followed by S2C4 and the value was 2.96. The highest value of MGT was recorded in case of S2C2 in both genotypes, which was 3.61 and 3.68 in V1 and V2, respectively. Germination index value of $Ca(NO_3)_2$ primed seeds was higher in S2C4 in both tomato genotypes V1 and V2, which was 158.67 and

Table 2. Effect of seed priming with different concentrations of $Ca(NO_3)_2$ salts on the germination percentage of two selected tomato varieties at different study periods of germination.

Treatment	GERMINATION PERCENTAGE (%)													
	24h		48h		72h		96h		120h		144h		168h	
	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2	V1	V2
S2C0	10±0a	6.67±5.77a	26.67±5.7abc	20±0b	53.33±5.77b	50±0cd	63.33±5.77b	60±0b	80±0bc	76.67±5.7bcd	86.67±5.77ab	83.33±5.77bc	86.67±5.77ab	83.33±5.77bc
S2C1	16.67±5.77a	13.33±5.77a	30±0ab	26.67±5.77ab	63.33±5.7bcd	60±0b	80±0a	76.67±5.77a	86.67±5.77ab	83.33±5.77b	93.33±5.77a	93.33±5.77ab	93.33±5.77a	96.67±5.77a
S2C2	10±0a	10±0a	20±0c	20±0b	43.33±5.77d	43.33±5.77d	60±0b	60±0b	73.33±5.77c	70±0d	86.67±5.77ab	83.33±5.77bc	86.67±5.77ab	86.67±5.77ab
S2C3	10±0a	10±0a	20±0c	20±0b	46.67±5.77cd	46.67±5.77cd	63.33±5.77b	60±0b	80±0bc	76.67±5.8bcd	86.67±5.77ab	86.67±5.77ab	86.67±5.77ab	86.67±5.77ab
S2C4	16.67±5.77a	16.67±5.77a	33.33±5.77a	33.33±5.77a	73.33±5.77a	70±0a	83.33±5.77a	80±0a	93.33±5.77a	93.33±5.77a	96.67±5.77a	96.67±5.77a	96.67±5.77a	96.67±5.77a
S2C5	10±0a	10±0a	23.33±5.77bc	23.33±5.77b	56.67±5.77bc	53.33±5.77bc	66.67±5.77b	63.33±5.77b	83.33±5.77b	80±0bc	90±0a	86.67±5.77ab	90±0a	86.67±5.77ab
S2C6	10±10a	10±10a	23.33±5.77bc	23.33±5.77b	56.67±5.77bc	53.33±5.77bc	63.33±5.77b	63.33±5.77b	73.33±5.77c	73.33±5.7cd	76.67±5.77b	73.33±5.77c	76.67±5.77b	76.67±5.77bc
S2C7	16.67±5.77a	13.33±5.77a	26.67±5.7abc	26.67±5.77ab	53.33±5.7bcd	53.33±5.77bc	66.67±5.77b	66.67±5.77b	73.33±5.77c	73.33±5.7cd	76.67±5.77b	73.33±5.77c	76.67±5.77b	73.33±5.77c
SEm±	1.021	1.102	.932	0.932	1.179	0.932	1.021	0.833	1.021	1.021	1.102	1.179	1.102	1.179
	P Value		P Value		P Value		P Value		P Value		P Value		P Value	
V	NS		NS		NS		NS		NS		NS		NS	
T	NS		**		**		**		**		**		**	
VxT	NS		NS		NS		NS		NS		NS		NS	

Variety: V1= VRT 06, V2= Punjab Chhuhara,
Salt: S2= $Ca(NO_3)_2$,
Concentration: C0= Control, C1= Hydra Priming, C2= 2.5mM,C3= 5mM, C4=7.5mM, C5= 10mM, C6= 15mM, C7=20mM
Data represent means of three replicates. Values with same letters are not significantly different at p≤0.05 according to DMRT post hoc test. * indicate significant level at p≤0.05 and ** indicate significant level at p≤0.01

155.67, respectively. While the lower GI was observed in S2C2 and the value was 112.67 and 111.0 in V1 and V2, respectively. The data of CVG value revealed that the higher CVG value was observed in S2C7 in both the genotypes followed by S2C4, while the lowest CVG value was observed in S2C2 in both the genotypes of tomato. The GRI value of both genotypes of tomato, primed with various concentrations of $Ca(NO_3)_2$ suggested that the lowest GRI value was observed in S2C2 in case of V1(31.83), while S2C0 had lowest GRI value in case of V2 (30.28). The highest GRI value was observed in S2C4 in case of both the genotypes, which was 43.39 and 42.92 in V1 and V2, respectively.

Table 3. Effect of seed priming with different concentrations of $Mg(NO_3)^2$ salts on the mean germination rate (MGR), germination index (GI), coefficient of velocity of germination, mean germination time (MGT) and germination rate index of two selected tomato varieties.

Treatment	MGT		GI		CVG		GRI	
	V1	V2	V1	V2	V1	V2	V1	V2
S1C0	3.29±0.25bc	3.44±0.1ab	125±0b	113.67±5.03d	30.46±2.48ab	29.13±0.87bcd	34.16±1.15b	30.28±3.42de
S1C1	3.03±0.26c	3.34±0.14bc	147.33±4.93a	139.33±4.51b	33.21±2.85a	29.97±1.26b	41.06±2.15a	38.76±0.7ab
S1C2	3.72±0.25a	3.76±0.13a	107.33±8.33d	102±2.65e	26.95±1.81b	26.66±0.94d	29.94±3.44b	28.55±1.55e
S1C3	3.57±0.28ab	3.63±0.17ab	113±12bcd	116±7.94d	28.12±2.11b	27.59±1.31bcd	31±4.31b	32.94±1.64cd
S1C4	2.96±0.12c	3.06±0.16c	155.33±7.02a	150.67±2.52a	33.79±1.32a	32.71±1.73a	42.83±1.44a	41.89±1.84a
S1C5	3.44±0.16ab	3.39±0.34b	122.67±10.79bc	125±6.25c	29.16±1.41b	29.75±3.11bc	33.78±3.19b	35.44±2.28bc
S1C6	3.27±0.16bc	3.6±0.06ab	119.67±1.53bcd	118.33±4.51cd	30.6±1.49ab	27.84±0.5bcd	33.61±1.87b	34.25±2.91c
S1C7	3.46±0.14ab	3.71±0.07b	110±5.57cd	100.67±2.89e	28.95±1.18b	26.98±0.53cd	32.17±3.35b	29.28±0.48de
SEm±	0.043	0.034	1.508	0.994	0.391	0.307	0.574	0.424
	P value		P value		P value		P value	
V	*		*		*		*	
T	**		**		**		**	
VxT	NS		NS		NS		NS	

Variety: V1= VRT 06, V2= Punjab Chhuhara,
Salt: S1= $Mg(NO_3)_2$,
Concentration:C0= Control, C1= Hydra Priming, C2= 2.5mM,C3= 5mM, C4=7.5mM, C5= 10mM, C6= 15mM, C7=20mM
Data represent means of three replicates. Values with same letters are not significantly different at pd"0.05 according to DMRT post hoc test.* indicate significant level at pd"0.05 and ** indicate significant level at pd"0.01

Table 4. Effect of seed priming with different concentrations of $Ca(NO_3)_2$salts on the mean germination rate (MGR), germination index (GI), coefficient of velocity of germination, mean germination time (MGT) and germination rate index of two selected tomato varieties.

Treatment	MGT		GI		CVG		GRI	
	V1	V2	V1	V2	V1	V2	V1	V2
S2C0	3.29±0.25abc	3.44±0.1ab	125±0cd	113.67±5.03cd	30.46±2.48abc	29.13±0.87cd	34.16±1.15b	30.28±3.42b
S2C1	3.03±0.26bc	3.34±0.14abc	147.33±4.93b	139.33±4.51b	33.21±2.85ab	29.97±1.26cd	41.06±2.15a	38.76±0.7a
S2C2	3.61±0.21a	3.68±0.27a	112.67±1.53e	111±2d	27.79±1.64c	27.27±2.08d	31.83±0.6b	31.64±0.43b
S2C3	3.46±0.09ab	3.54±0.03a	117.67±6.11de	115.33±6.35cd	28.93±0.75bc	28.28±0.25d	32.5±1.61b	32.22±1.64b
S2C4	2.89±0.22c	2.96±0.16abc	158.67±3.79a	155.67±3.51a	34.75±2.63a	33.86±1.93ab	43.39±1.09a	42.94±2.99a
S2C5	3.33±0.11abc	3.33±0.39bcd	128±6c	123±6.93c	30.02±1abc	30.35±3.84bcd	34.72±1.35b	33.61±0.77b
S2C6	3.03±0.28bc	3.12±0.26cd	119.67±3.06cde	117.33±4.93cd	33.2±3.21ab	32.21±2.69abc	32±4.04b	31.64±4.28b
S2C7	2.9±0.34c	2.82±0.09d	126±6.56cd	122.67±8.33c	34.81±4.06a	35.54±1.13a	35.78±2.62b	33.56±3.71b
SEm±	.048	.043	.932	1.127	.522	.419	.427	.543
	P value		P value		P value		P value	
V	NS		**		NS		NS	
T	**		**		**		**	
VxT	NS		NS		NS		NS	

Variety : V1= VRT 06, V2= Punjab Chhuhara,
Salt: S2= $Ca(NO_3)_2$
Concentration:C0= Control, C1= Hydra Priming, C2= 2.5mM,C3= 5mM, C4=7.5mM, C5= 10mM, C6= 15mM, C7=20mM
Data represent means of three replicates. Values with same letters are not significantly different at p≤0.05 according to DMRT post hoc test. * indicate significant level at p≤0.05 and ** indicate significant level at p≤0.01

Seedling parameter

Table 5 represent the seedling parameters of two tomato genotypes VRT 06 (V1) and Punjab chhuhara (V2), which were primed with various concentration of $Mg(NO_3)_2$. The data of seedling length revealed that the lowest seedling length was observed in S1C7 (20 mM) in case of V1, which was 8.73 cm and in V2, it was 12.07 cm, which was observed in S1C2 (2.5 mM). While the highest seedling length was found in S1C4 in case of both genotypes, which was 15.37 cm. and 14.73 cm in V1 and V2, respectively. The data of Seedling fresh weight of $Mg(NO_3)_2$ primed seeds revealed that the highest seedling fresh weight was observed in S1C4 in case of both genotypes, which was 28.03 mg and 27.83 mg in V1 and V2, respectively. While the lowest seedling fresh weight was observed in S1C7 in case of V1 (19.87 mg) and S1C2 in V2 (21.57 mg). The data of seedling dry weight of $Mg(NO_3)_2$ primed seeds revealed that the higher seedling DW was observed in S1C4 in both the genotypes, which was 3.17 mg and 2.47 mg in V1 and V2, respectively. While the lowest value of seedling DW was observed in S1C7 in V1 and S1C0 in V2, which was 1.9 mg and 1.57 mg, respectively in case of V1 and V2. Seedling establishment and growth is the important feature of any crop, which is indicated by seedling vigor. The data of seedling vigor (SV) suggested that the highest SV value was found in S1C4 in both genotypes, which was 1484.67 and 1425 in V1 and V2, respectively. While the lowest value of SV was observed in S1C7, which was 698.67 and 1005.33 in V1 and V2, respectively.

Table 6 represent the seedling parameters of two tomato genotypes VRT 06 (V1) and Punjab chhuhara (V2), which was primed with various concentration of $Ca(NO_3)_2$. The data of seedling length revealed that the highest seedling length was observed in S2C4 (7.5 mM) in both genotypes, which was 14.6 cm and 14.53 cm in V1 and V2, respectively, followed by S2C1 with value 14.35 cm in V1 and 14.47 cm in V2. The lowest value of seedling length was observed in S2C7 treatment, and the value was 8.6 cm and 10.07 cm in V1 and V2, respectively. The data of seedling FW suggested that the highest value of seedling FW was observed in S2C4 in both the genotypes, which was 27.87 mg and 28.03 mg in V1 and V2, respectively. Whereas, in case of V1, the lowest value of seedling FW was 20.03mg, observed in S2C7, while in case of V2, the lowest value was 20.97 mg, found in S2C2. The represented data of seedling DW suggested that the highest seedling DW was observed in S2C4 in both the genotypes, which was 3 mg and 2.37 mg in V1 and V2, respectively. Whereas, the lowest value of seedling DW was 1.93 mg in V1, observed in S2C7, while in case of V2, the lowest value was 1.33 mg, observed in S2C0. The data of SVI of $Ca(NO_3)_2$

Table 5. Effect of seed priming with different concentrations of $Mg(NO_3)_2$ salts on Seedling Length, Seedling Fresh Weight, Seedling Dry Weight, Seedling Vigor Index of two selected tomato varieties at different study periods of germination.

Treatment	Seedling Length		Seedling Fresh Weight		Seedling Dry Weight		Seedling Vigor Index	
	V1	V2	V1	V2	V1	V2	V1	V2
S1C0	12.93±0.15d	12.67±0.64bc	24.67±0.4c	23.4±0.2e	2.83±0.15b	1.33±0.12e	1121.33±84.77cd	1054±55.24de
S1C1	14.35±0.24b	14.47±0.15a	27.17±0.25b	26.67±0.15b	2.93±0.15b	2.1±0.17b	1338.27±65.09b	1398.33±82.21b
S1C2	11.47±0.21f	12.07±0.15c	20.07±0.15f	21.57±0.15f	2.3±0.1c	1.67±0.06cd	994±73.26de	1006±80.07e
S1C3	12.13±0.25e	13.57±0.4ab	21.43±0.06e	25.63±0.21c	2.47±0.12c	1.83±0.06c	1052.33±87.93de	1221±36.37cd
S1C4	15.37±0.21a	14.73±0.21a	28.03±0.21a	27.83±0.06a	3.17±0.06a	2.47±0.12a	1484.67±70.04a	1425±104.04a
S1C5	13.8±0.3c	14.13±0.21a	22.87±0.31d	24.97±0.21d	2.77±0.06b	2.1±0.1b	1241±128bc	1270.67±123.16bc
S1C6	11.37±0.15f	12.3±1.28bc	22.47±0.32d	23.17±0.21e	2.27±0.12c	1.77±0.06cd	947.33±69.18e	1107±114.9cde
S1C7	8.73±0.55g	12.57±1.52bc	19.87±0.21f	23.37±0.25e	1.9±0.1d	1.57±0.15d	698.67±44.06f	1005.33±121.41e
SEm±	.058	.156	.053	.038	.023	.023	16.542	19.295
	P Value		P Value		P Value		P Value	
V	**		**		**		**	
T	**		**		**		**	
VxT	**		**		**		*	

Variety: V1= VRT 06, V2= Punjab Chhuhara,
Salt: S1= $Mg(NO_3)_2$,
Concentration: C0= Control, C1= Hydra Priming, C2= 2.5mM,C3= 5mM, C4=7.5mM, C5= 10mM, C6= 15mM, C7=20mM
Data represent means of three replicates. Values with same letters are not significantly different at p≤0.05 according to DMRT post hoc test. * indicate significant level at p≤0.05 and ** indicate significant level at p≤0.01

Table 6. Effect of seed priming with different concentrations of $Ca(NO_3)_2$ salts on Seedling Length, Seedling Fresh Weight, Seedling Dry Weight, Seedling Vigor Index of two selected tomato varieties at different study periods of germination.

Treatment	Seedling Length		Seedling Fresh Weight		Seedling Dry Weight		Seedling Vigor Index	
	V1	V2	V1	V2	V1	V2	V1	V2
S2C0	12.93±0.15bc	12.67±0.64abc	24.67±0.4c	23.4±0.2d	2.83±0.15ab	1.33±0.12d	1121.33±84.77bc	1054±55.24bcd
S2C1	14.35±0.24a	14.47±0.15a	27.17±0.25b	26.67±0.15b	2.93±0.15a	2.1±0.17b	1338.27±65.09a	1398.33±82.21a
S2C2	11.13±0.21d	11.17±0.15cd	21.37±0.21f	20.97±0.21e	2.17±0.12d	1.93±0.12b	964.33±53.97cd	968.33±76.63cd
S2C3	13.63±0.15ab	13.23±1.25ab	23.17±0.25d	25.5±0.26c	2.4±0.1c	2.07±0.12b	1182±88.79b	1147±137.36bc
S2C4	14.6±0.1a	14.53±0.21a	27.87±0.06a	28.03±0.12a	3±0.1a	2.37±0.06a	1411.67±92.51a	1404.33±72.02a
S2C5	12.23±1.38cd	13.9±1.48a	22.07±0.06e	26.53±0.38b	2.63±0.06b	2.13±0.06b	1101±124.17bc	1207±178.5ab
S2C6	11.77±0.99d	11.5±1.93bcd	22.07±0.21e	25.33±0.12c	2.23±0.06cd	1.7±0.1c	904.33±127.5d	874.67±84.79de
S2C7	8.6±0.1e	10.07±1.33d	20.03±0.31g	23.27±0.21d	1.93±0.15e	1.47±0.12d	659±43.49e	743.33±159.93e
SEm±	.126	0.225	.050	0.045	.024	0.023	18.306	23.315
	P value		P value		P value		P value	
V	NS		**		**		NS	
T	**		**		**		**	
VxT	NS		**		**		NS	

Variety: V1= VRT 06, V2= Punjab Chhuhara,
Salt: S2= $Ca(NO_3)_2$
Concentration:C0= Control, C1= Hydra Priming, C2= 2.5mM, C3= 5mM, C4=7.5mM, C5= 10mM, C6= 15mM, C7=20mM
Data represent means of three replicates. Values with same letters are not significantly different at p≤0.05 according to DMRT post hoc test. * indicate significant level at p≤0.05 and ** indicate significant level at p≤0.01

primed seeds revealed that the highest value of SVI was observed in case of S2C4, which was 1411.67 and 1404.33 in V1 and V2, respectively. Whereas the lowest value of SVI was observed in S2C7 in both the genotypes, which was 659 and 743.33 in V1 and V2, respectively.

Discussion and Conclusion

In the present study, effect of seed priming with various concentrations of $Mg(NO_3)_2$ (S1) and $Ca(NO_3)_2$ (S2) salts on germination and seedling growth were carried out using two tomato genotypes VRT 06 and Punjab chhuhara. Optimum concentration of nutrients is capable to regulate various cellular and metabolic processes and enhance capacity to sustain integrity and proper activity of plants. Various studies provoke that seed treatment with various inorganic/organic substances before sowing helps in improving germinability and performance of crops seeds (Nafees *et al.,* 2019). In the present study primed seed with suitable concentration of salts and hydropriming (C2) showed better performance in respect to non-primed (C0) and other treatments. A number of studies showed similar enhancement strategy in germination and seedling establishment of crops in case of all the used mineral salts (Barbosa *et al.,* 2016; Salles *et al.,* 2019; Kumar *et al.,* 2020; Choudhary *et al.,* 2021).

MGT is a germination parameter which is a precise measure of the time taken for a lot of seeds to germinate, but the measurement does not account for the spread or the uniformity of germination over time. It does focus on the day when most germination events occur. The germination index (GI) seems to be the most comprehensive measurement, given that it combines both germination percentage and speed of germination. It magnifies the variation among the following priming treatment with an easily compared numerical analysis. GRI simply measures the percentage of germination per day. Higher germination percentage and lower germination time, represent higher GRI value. CVG emphasize on the time required for attending maximum germination percentage. Higher CVG is possible by increase in number of germinated seeds with decrease in time taken for germination (Kader, 2005). Data of CVG revealed that optimum concentration of priming salts and hydro-priming treatment show higher CVG as compared to other treatment, due to improvement in velocity of germination and decrease in the time taken for start of germination. Studies regarding analysis of germination parameters including MGT, GI, GRI, CVG, and MGR also showed better performance in case of priming with suitable concentration of salts, while non-primed seeds observed undesirable result in above germination parameters (Gouveia *et al.,* 2017; Chakraborty and

Bose, 2020; Singhal and Bose, 2020).

Seedling growth and vigor arecrucial quality traitsfor assessment of germination and seed viability in field condition to understand the priming performance of seeds. Seedling establishment and health is also significantly associated with genetic and environment factors. Present studies showed better performance of hydroprimed and seed primed with suitable concentration as compared to nonprimed and other primed seeds in case of seedling growth and SV. Previous studies supported that germination and seedling parameters improved in response to seed priming with use of $Mg(NO_3)_2$ and $Ca(NO_3)_2$ in wheat, okra and papaya (Maneesha, 2019; Choudhary *et al.,* 2021). Seedling length, fresh and dry weight, and seedling vigor of primed tomato seed were also improved by 7.5mM $Mg(NO_3)_2$ priming treatment (Nafees *et al.,* 2019). Therefore, this study concludes that seed priming with suitable concentration of salts and hydro-primed seeds treatment improved the seed germination parameters, seedling growth, seedling vigor, and sustained seeds quality which helped in early emergence, vigorous growth and strong establishment of seedling.

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