

Effects of Different Doses of Ethyl Methane Sulphonate (EMS) On Germination and Growth Attributes of Two Tomato Varieties

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Abstract

Varietal response and appropriate use of chemical mutagens play a crucial role in improving tomato germination and early seedling growth. To assess the effect of different doses of Ethyl Methane Sulphonate (EMS) on the germination and seedling growth of tomato, an experiment was conducted at the Tissue Culture Laboratory, Horticulture Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from October 2024 to December 2024. The experiment included two tomato varieties—BARI Tomato-12 and BARI Tomato-18—and four EMS treatments: Control (0%), 0.5% EMS, 1% EMS, and 1.5% EMS. The study was laid out in a Completely Randomized Design (CRD) with three replications. Data were recorded on germination percentage, plumule length, radicle length, root length, number of roots and leaves per plant, plant height, and canopy volume at different growth stages. Results of the study showed that EMS treatment significantly influenced all measured traits. Among the treatments, 0.5% EMS exhibited the best performance in terms of seed germination (98%), shoot and root elongation, plant height (13.73 cm), and canopy volume ($1.39E^{-3} \text{ m}^3$), while higher EMS doses showed inhibitory effects on seedling development. Between the two varieties, BARI Tomato-12 performed better across all parameters than BARI Tomato-18. The interaction effect showed that the combination of BARI Tomato-12 $\times$ 0.5% EMS gave the most promising results in terms of overall seedling vigor and growth performance. Therefore, the study suggests that 0.5% EMS can be used as an effective dose to improve early seedling growth in tomato, especially in BARI Tomato-12, for potential use in mutation breeding programs. However, further field trials and molecular assessments are recommended to validate the stability and long-term impact of EMS-induced changes.

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I. Introduction

Tomato (*Solanum lycopersicum* L.) is a globally significant vegetable crop cultivated extensively for its high nutritional value and diverse culinary applications. With an estimated annual production exceeding 180 million tons worldwide, tomato ranks as the second most important vegetable crop after potato in terms of production volume (FAOSTAT, 2023). Tomatoes contribute substantially to global food security by providing a rich source of vitamins (A, C, and E), minerals such as potassium, dietary fiber, and bioactive compounds like lycopene, a powerful antioxidant linked to reduced risk of chronic diseases including cardiovascular ailments and certain cancers (Willcox *et al.*, 2003). Its versatility allows it to be consumed fresh, cooked, or processed into products such as sauces, pastes, juices, and canned goods, making it a staple ingredient in many cuisines worldwide (Bhatia, 2010). In Bangladesh, tomato production plays a crucial role in the national vegetable sector and the livelihoods of many smallholder farmers. Cultivated predominantly during the winter season, tomato occupies roughly 30,000 hectares with an average annual production of about 400,000 metric tons (BBS, 2024). The crop contributes significantly to the country's nutritional intake by providing essential micronutrients and antioxidants that are otherwise limited in the typical Bangladeshi diet (Hossain and Sultana, 2021). Despite favorable climatic conditions, Bangladesh's average tomato yield—about 13 to 15 tons per hectare—lags behind global averages, which often exceed 30 tons per hectare in leading producing countries (BBS, 2024; Rahman *et al.*, 2021). Several factors, including poor-quality seeds, inadequate crop management, pest and disease pressures, and a narrow genetic base of cultivated varieties, contribute to this yield gap (Uddin *et al.*, 2017; Roy *et al.*, 2018). One of the major production constraints in Bangladesh is low germination rate and poor seedling vigor, especially under

unfavorable environmental conditions such as high humidity, erratic rainfall, and soil-borne pathogens (Khatun *et al.*, 2020). These issues hinder proper canopy establishment, reduce seed germination, plant growth and ultimately affect yield. Additionally, local tomato cultivars often lack of optimum seed germination, sufficient canopy volume, deeper root development, and plant height that are essential for optimal nutrient absorption and photosynthesis (Nasrin *et al.*, 2016; Das *et al.*, 2020). Among the various chemical mutagens, Ethyl Methane Sulphonate (EMS) is one of the most widely used and effective agents due to its ability to induce high-frequency point mutations without causing gross chromosomal aberrations (Sikora *et al.*, 2011; Talebi *et al.*, 2012). The effectiveness of EMS is highly dose-dependent and varies significantly among genotypes. An overdose can be phytotoxic, leading to reduced germination, chlorosis, or even lethality, while sub-optimal doses may not induce useful mutations (Kumar *et al.*, 2013). Varietal performance is influenced by factors such as seed germination capacity, seedling vigor, canopy development, plant height, and root architecture (Nasrin *et al.*, 2016; Das *et al.*, 2020). The identification and selection of varieties that respond well to mutation breeding techniques like EMS treatment can lead to the development of improved tomato cultivars better suited for local cultivation with maximum germination and proper growth. Therefore, identifying the most effective EMS concentration and suitable variety is critical for achieving the desired improvements without compromising seed viability. So the present study was undertaken with the following objectives: i) to select the suitable variety of tomato; ii) to find out the most effective EMS dose in relation to seed germination and growth characteristics of tomato and iii) to assess the effect of interaction between suitable EMS dose and variety on seed germination and growth.

II. Materials and Methods

The experiment was carried out at the Tissue Culture Laboratory, Horticulture Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from October 2024 to December 2024 to assess the effects of different doses of ethyl methane sulphonate (EMS) on germination and growth attributes of two tomato varieties. A single factor experiment consisted of factor A: Tomato Varieties: BARI Tomato-12 (V1) and BARI Tomato-18 (V2) and factor B: Ethyl Methane Sulphonate (EMS) Concentration: Control (T0); EMS Dose 0.5 % (T1); EMS Dose 1 % (T2) and EMS Dose 1.5 % (T3). The experiment was laid out in a Completely randomized design (CRD) with three replications. The whole experiment was conducted in beaker, petri dishes and trays. At first Tomato seeds of two varieties were kept soaked in 8 beaker containing different EMS solution and two beakers containing only water as control for 24 hours. After that the treated seeds were placed in 24 petri dishes among them 18 were contained treated seeds with EMS solution and 6 for control seeds for 7 days to germinate and seedling rising. After that the germinated seedlings were transplanted in 36 rooms of 2 trays and in each room 1 seedling was transplanted as my experiment containing 2 varieties 3 replication and 4 treatments (EMS concentration). So total rooms of the trays were $3 \times 4 \times 2 = 36$. Seeds of the test varieties were collected from the Horticulture division of Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh. The solution of 25 ppm was prepared by dissolving 25 mg of Ethyl Methane Sulphonate (EMS) in 1000 ml distilled water. Thus 50 ppm and 75 ppm solutions were prepared by dissolving 50 mg and 75 mg of (EMS) in 1000 ml distilled water. Germination is the emergence of seedling which was conducted using Petri dish method. At first 200 seeds of each of tomato varieties were soaked for 24 hours in different Ethyl Methane Sulphonate (EMS) solutions with different ppm were used for particular treatment of seeds and distilled water was used in control. After 24 hours, the seeds were removed and placed in Petri dishes for germination. Germination paper was folded and cut in a size of Petri dish and were used in each Petri dish as substrate. 200 seeds of each of tomato varieties were kept for germination in two folds of Whatman no.1 filter paper placed in Petri dishes (11 cm diameter). Each treatment was replicated three times. The Petri dishes were kept at under constant incubator temperature set at $25 \pm 1^{\circ}\text{C}$ for 11 days in the laboratory. Proper moisture was controlled during the period. Seven-day-old seedlings were uprooted on 10 November 2024 and they were immediately transferred to the trays. Healthy and similar-sized seedlings were selected for transplanting. Seedlings were transplanted in the well-prepared trays by compost at the rate of one seedling room^{-1} of the trays on 10 November 2024. In this study, data on yield and yield-contributing characters were recorded from five randomly selected sample plants from each plot on the following parameters: germination (%), plumule length (cm), radicle length (cm), number of roots per plant, length of longest root (cm), number of leaves per plant, plant height (cm), canopy volume (m^3). The recorded data were compiled and tabulated for statistical analysis. Analysis of variance was done with the help of computer package, MSTAT. The mean differences among the treatments were adjudged by Duncan's Multiple Range Test (Gomez and Gomez, 1984).

III. Results and Discussion

Effect of Variety

The present study revealed significant varietal differences in several seedling growth traits, including germination percentage, plumule length, radicle length, root length, number of roots and leaves per plant, plant height and canopy volume. Between the two tested tomato varieties: BARI Tomato-12 (V₁) and BARI Tomato-18 (V₂). BARI Tomato-12 consistently outperformed BARI Tomato-18 in terms of early growth and development.

Germination percentage:

In terms of germination percentage, BARI Tomato-12 exhibited significantly faster and higher germination at early stages (3 DAS), which may be attributed to its better seed vigor and genetic potential for stress tolerance. At 3 DAS, the highest germination percentage (50.16%) was recorded in BARI Tomato-12, which was significantly greater than BARI Tomato-18 (23.50%). However, at 5 and 7 DAS, both varieties showed statistically similar germination percentages (Fig. 1). The initial difference in germination rate can be attributed to the genetic makeup and seed vigor of the varieties. BARI Tomato-12, being an early and vigorous type, responded more actively in early stages. This observation aligns with findings reported by Sengupta *et al.*, (2015), who stated that varietal differences in seed vigor play a key role in determining early germination behavior.

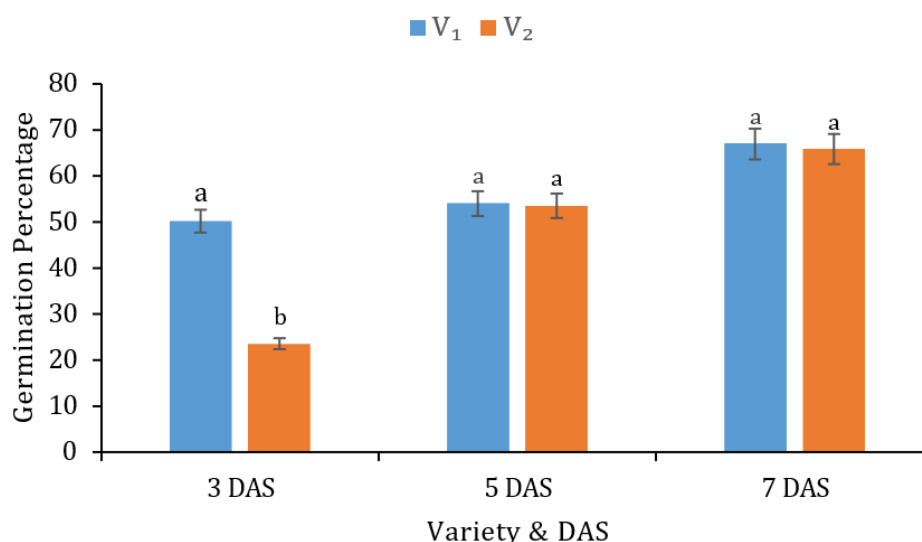


Fig. 1: Effect of Germination Percentage on Variety

Here, V₁ = BARI Tomato-12, V₂ = BARI Tomato-18 and DAS = Days After Sowing, Vertical bars indicate the standard error of the mean. Figures with the same letter do not differ significantly, whereas figures with dissimilar letters differ significantly ($P \leq 0.05$).

Plumule length:

Plumule length was significantly influenced by tomato variety at all observation stages (3, 5, and 7 DAS). At 3 DAS, BARI Tomato-12 recorded the longest plumule (1.04 cm), which was significantly higher than BARI Tomato-18 (0.65 cm). Similar trends continued at 5 and 7 DAS, where BARI Tomato-12 maintained significantly greater plumule elongation (2.22 cm and 3.15 cm, respectively) compared to BARI Tomato-18 (1.40 cm and 2.36 cm, respectively) (Table 1). These results indicate that BARI Tomato-12 possesses higher early shoot growth potential, likely due to stronger apical meristem activity and early vigor.

Radicle length:

Radicle length was not significantly influenced by tomato variety at 3 and 5 days after sowing (DAS), but a significant difference was observed at 7 DAS. At 7 DAS, BARI Tomato-12 recorded a significantly longer root (2.95 cm) compared to BARI Tomato-18 (2.51 cm) (Appendix I). Although differences at earlier stages were statistically non-significant, BARI Tomato-12 consistently showed slightly higher root length throughout the period. This trend may be attributed to the stronger seedling vigor and more active root meristem in BARI Tomato-12. The findings are consistent with those of Islam *et al.*, (2019), who

reported varietal differences in root elongation due to genetic variation in root development potential (Table 1).

Root Length (cm)

The analysis of root length across two varieties (BARI Tomato-12 and BARI Tomato-18) at different time points (14, 21, 28, 35, and 42 days) revealed no significant difference between the varieties from day 14 through day 35. However, at 42 days, the root length showed a statistically significant difference, indicating varietal effect at this stage. Specifically, variety BARI TOMATO-12 exhibited consistently greater root lengths at all measured intervals, culminating in a root length of 8.54 cm at 42 days, compared to 7.49 cm in variety BARI Tomato-18 (Table 1).

Number of Roots per Plant:

The number of roots per plant was not significantly affected by variety at 7 DAS, but significant differences were observed from 14 DAS onwards. At 14 DAS, BARI Tomato-12 produced the highest number of roots per plant (2.25), while BARI Tomato-18 produced fewer roots (1.58). This trend continued at 21, 28, 35, and 42 DAS, where BARI Tomato-12 consistently showed higher root numbers than BARI Tomato-18 (Fig. 2). This reflects greater meristematic activity and better seedling vigor, which are crucial for early biomass accumulation and subsequent plant development (Kumar *et al.*, 2019).

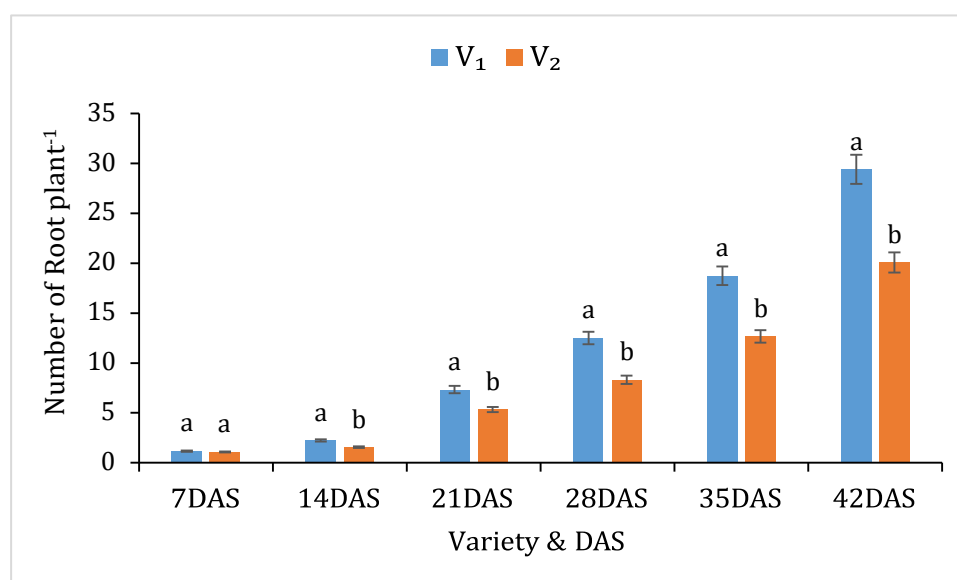


Fig. 2: Effect of Number Root Plant⁻¹ on the Variety

Here, V₁ = BARI Tomato-12, V₂ = BARI Tomato-18 and DAS = Days After Sowing, Vertical bars indicate the standard error of the mean. Figures with the same letter do not differ significantly, whereas figures with dissimilar letters differ significantly ($P \leq 0.05$).

Number of Leaves per Plant

The number of leaves per plant was significantly affected by variety only at 7 DAS, while differences at later stages (14, 21, 28, 35, and 42 DAS) were non-significant. At 7 DAS, BARI Tomato-12 produced a significantly higher number of leaves (1.0) compared to BARI Tomato-18 (0.25). At all subsequent stages, both varieties showed statistically similar leaf counts (Fig. 3)

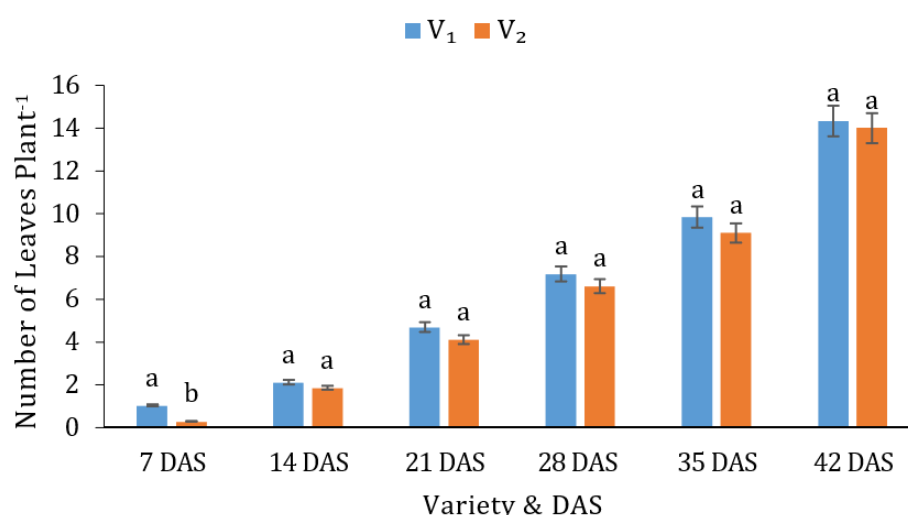


Figure 4.5: Effect of Number Leaves Plant⁻¹ on the Variety

Here, V₁ = BARI Tomato-12, V₂ = BARI Tomato-18 and DAS = Days After Sowing, Vertical bars indicate the standard error of the mean. Figures with the same letter do not differ significantly, whereas figures with dissimilar letters differ significantly ($P \leq 0.05$).

Plant height:

Plant height was significantly affected by variety at 14, 21, 35, and 42 DAS, while the difference at 28 DAS was non-significant. BARI Tomato-12 recorded higher plant heights at all stages compared to BARI Tomato-18. At 14 DAS, plant height was 4.98 cm for BARI Tomato-12 and 3.87 cm for BARI Tomato-18. At 21 DAS, the values were 6.46 cm and 5.38 cm, respectively. At 28 DAS, both varieties were statistically similar, while at 35 and 42 DAS, BARI Tomato-12 maintained higher plant height with 9.88 cm and 12.08 cm, respectively (**Table 1**). This reflects greater meristematic activity and better seedling vigor, which are crucial for early biomass accumulation and subsequent plant development (Kumar *et al.*, 2019).

Canopy Volume (m³)

Canopy volume was significantly affected by variety at all DAS except 35 DAS. At 14 DAS, BARI Tomato-12 recorded 9.07×10^{-6} m³ versus 4.31×10^{-6} m³ in BARI Tomato-18. At 21 DAS these values were 5.15×10^{-5} m³ and 2.47×10^{-5} m³; at 28 DAS, 1.84×10^{-4} m³ and 1.11×10^{-4} m³; and at 42 DAS, 8.33×10^{-4} m³ and 4.68×10^{-4} m³ for BARI Tomato-12 and BARI Tomato-18, respectively. At 35 DAS both varieties were statistically similar (8.60×10^{-4} m³ and 1.75×10^{-4} m³) (**Table 1**).

Table 1: Effect of Variety on the Germination and Growth Contributing Parameters

Variety	Plumule Length (cm)			Radicle Length (cm)			Root Length (cm)				
	3 DAS	5 DAS	7 DAS	3 DAS	5 DAS	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS
V ₁	1.04a	2.22a	3.15a	1.18a	2.07a	2.95a	1.56a	2.72a	4.00a	5.9a	8.54a
V ₂	0.65b	1.4b	2.36b	1.02a	2.04a	2.51b	1.36a	2.26a	3.55a	5.22a	7.49b
Level of significance	**	**	**	NS	NS	**	NS	NS	NS	NS	**
CV%	23.27	12.48	16.09	27.0	17.94	14.78	18.31	25.78	15.01	15.41	10.44
LSD(0.05)	0.017	0.19	0.38	0.26	0.32	0.35	0.23	0.56	0.49	0.75	0.73

Variety	Plant Height (cm)						Canopy Volume (m ³)				
	7DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	14DAS	21 DAS	28DAS	35 DAS	42DAS
V1	2.95a	4.98a	6.46a	7.51a	9.88a	12.08a	9.07E-06 a	5.15E-05 a	1.84E-4 a	8.6E-4 a	8.33E-4 a
V2	2.35b	3.87b	5.38b	6.85a	8.55b	10.7b	4.31E-06 b	2.47E-05 b	1.11E-4 b	1.75E-4 b	4.68E-4 b
Level of significance	**	**	**	NS	**	**	**	**	**	NS	**
CV%	10.65	10.23	9.85	10.63	13.02	12.57	17.04	24.69	15.07	222.81	17.25
LSD(0.05)	0.24	0.39	0.51	0.67	1.05	1.25	9.99E-07	8.24E-06	1.95E-5	1.01E-3	9.82E-5

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 5% level of probability, NS = Not significant, V1 = BARI Tomato-12, V2 = BARI Tomato-18 and DAS=Days After Sowing

Effect of EMS

Germination percentage was significantly affected by EMS treatment at all observed stages (3, 5, and 7 DAS). The highest germination (47.00%, 81.00%, and 91.67%) was observed in 0.5% EMS treatment, while the lowest germination rates were recorded in the 1.5% EMS treatment (28.00%, 25.00%, and 32.33%, respectively) (**Fig. 4**). The increased germination at 0.5% EMS may be due to enhanced enzymatic activity and seed metabolism at low EMS concentration. In contrast, higher EMS levels likely caused damage to seed cells, reducing their viability. This aligns with the findings of Wani *et al.* (2011), who reported that low doses of EMS can break seed dormancy and accelerate enzymatic processes involved in germination. Conversely, germination was significantly reduced in T2 and T3, suggesting inhibitory effects at higher EMS levels due to DNA damage or disruption of cellular metabolism (Kumar & Singh, 2014).

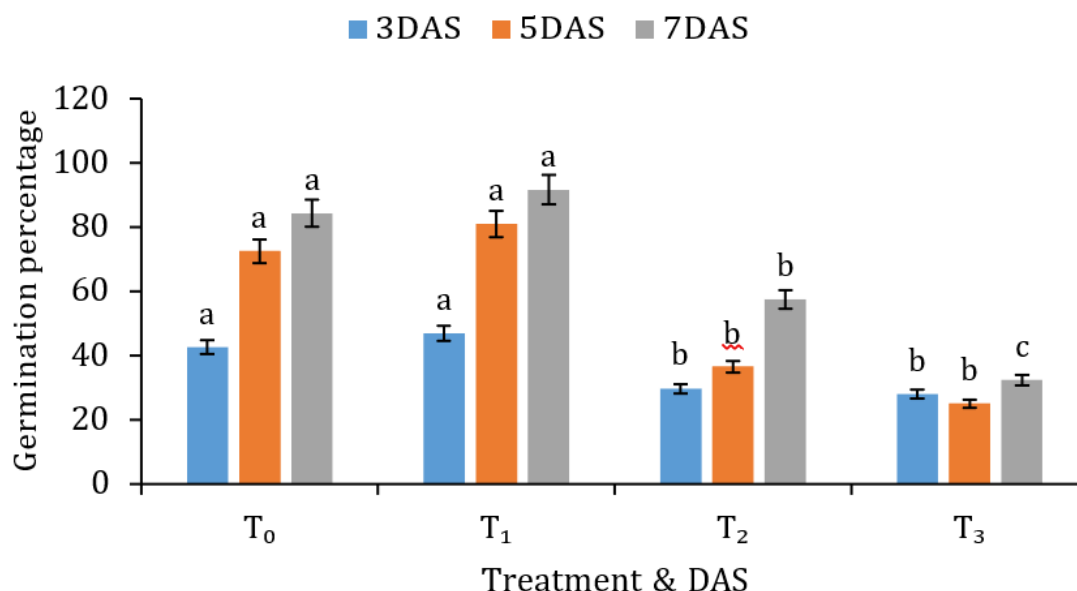


Fig. 4: Effect of Germination Percentage on Treatment

Here, T₀ = Control, T₁ = EMS Dose 0.5 %, T₂ = EMS Dose 1 %, T₃ = EMS Dose 1.5

% and DAS = Days after sowing, Vertical bars indicate the standard error of the mean. Figures with the same letter do not differ significantly, whereas figures with dissimilar letters differ significantly ($P \leq 0.05$).

Plumule length:

Plumule length was significantly affected by EMS treatment at all stages of observation (3, 5, and 7 DAS). The maximum plumule length was recorded in the 0.5% EMS treatment, with values of 1.11 cm, 2.28 cm, and 3.23cm at 3, 5, and 7 DAS, respectively. In contrast, the lowest plumule lengths were

recorded in the 1.5% EMS treatment (0.63 cm, 1.50 cm, and 2.38 cm, respectively) (**Table 2**). However, higher doses of EMS appeared to negatively impact plumule elongation, likely due to increased chromosomal aberrations and cell cycle arrest (Adamu & Aliyu, 2007).

Radicle length:

Radicle length was significantly affected by EMS treatments at 7 DAS, while differences at 3 and 5 DAS were non-significant. At 7 DAS, the longest roots (3.28 cm) were observed in the 0.5% EMS treatment, followed by the control (2.95 cm), while the shortest roots were recorded in the 1.5% EMS treatment (2.10 cm). This indicates that low concentrations of EMS may stimulate root cell elongation, while higher concentrations cause cellular damage, reducing root growth (**Table 2**).

Root length:

Significant differences were observed among treatments at 14, 21, 28, and 35 DAS, while no significant difference was found at 42 DAS. At 14 DAS, 0.5% EMS treatment showed the highest root length (1.76 cm), significantly greater than 1% EMS (1.26 cm) and 1.5% EMS (1.23 cm). This trend continued at 21 DAS and 28 DAS, with 0.5% EMS consistently having the longest roots (3.11 cm and 4.33 cm respectively) compared to other treatments. At 35 DAS, 0.5% EMS and control showed comparable root lengths (6.13 cm and 6.1 cm respectively), both significantly higher than 1% EMS (4.55 cm) and 1.5% EMS (5.46 cm). However, by 42 DAS, root length among all treatments was not significantly different (**Table 2**). Root growth suppression in T₂ and T₃ treatments supports the hypothesis that excessive EMS causes cytotoxic effects that reduce root meristem activity and elongation (Shah *et al.*, 2008).

Number of roots per plant

Significant differences in number of roots per plant were found among EMS treatments at all stages except 7 DAS. The maximum number of roots was recorded in the 0.5% EMS treatment at all stages—1.33 (7 DAS), 2.5 (14 DAS), 8.33 (21 DAS), 12.33 (28 DAS), 18.67 (35 DAS), and 30.16 (42 DAS). The lowest number of roots was observed in the 1.5% EMS treatment across all growth stages (**Fig. 4**). The lower values recorded in T₂ and T₃ treatments may be due to disrupted auxin and cytokinin balance, which plays a critical role in root and shoot initiation (Silva *et al.*, 2014)

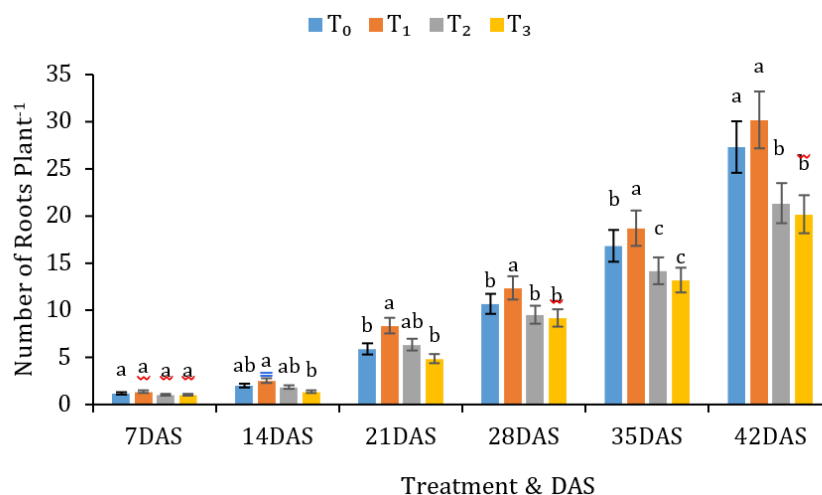


Fig. 5: Effect of Number Roots Plant⁻¹ on Treatment

Here, T₀ = Control, T₁ = EMS Dose 0.5 %, T₂ = EMS Dose 1 %, T₃ = EMS Dose 1.5 % and DAS = Days After Sowing, Vertical bars indicate the standard error of the mean. Figures with the same letter do not differ significantly, whereas figures with dissimilar letters differ significantly ($P \leq 0.05$).

Number of leaves per plant:

EMS treatment had a significant effect on number of leaves per plant at 7, 35, and 42 DAS, while no significant differences were observed at 14, 21, and 28 DAS. The highest number of leaves was recorded in the 0.5% EMS treatment at all stages, with values of 1.33 (7 DAS), 2.33 (14 DAS), 5.00 (21 DAS), 7.66 (28 DAS), 11.5 (35 DAS), and 16.83 (42 DAS). The lowest number of leaves was observed in the 1.5% EMS treatment, especially at 7 DAS (0.0) (**Fig. 6**).

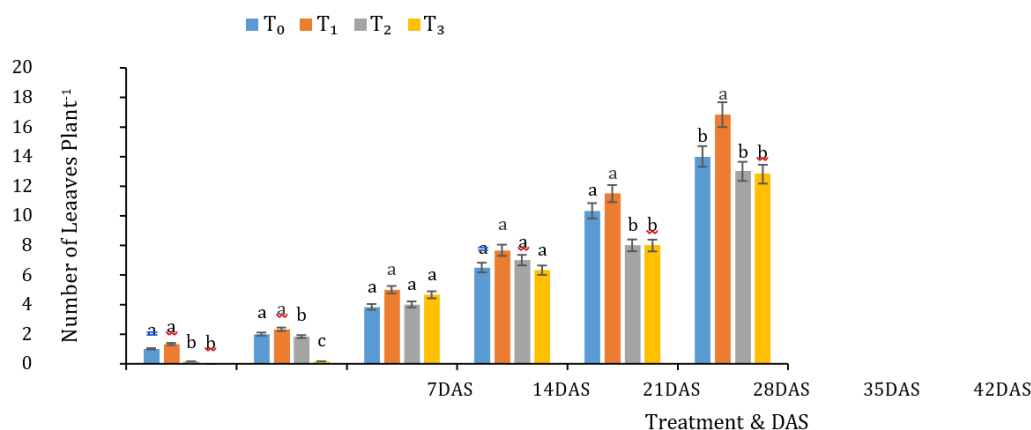


Fig. 6: Effect of Number Roots Plant⁻¹ on Treatment

Here, T₀ = Control, T₁ = EMS Dose 0.5 %, T₂ = EMS Dose 1 %, T₃ = EMS Dose 1.5

% and DAS = Days After Sowing, Vertical bars indicate the standard error of the mean. Figures with the same letter do not differ significantly, whereas figures with dissimilar letters differ significantly ($P \leq 0.05$).

Plant height:

Plant height varied significantly among EMS treatments at 14, 21, 28, and 42 DAS, while it was non-significant at 35 DAS. The tallest plants were observed in the 0.5% EMS treatment at all stages, with heights of 4.73 cm (14 DAS), 6.51 cm (21 DAS), 7.95 cm (28 DAS), 9.86 cm (35 DAS), and 11.71 cm (42 DAS). The shortest plants were found in the 1.5% EMS treatment across all stages (Table 2).

The inhibitory effects at 1% and 1.5% EMS may reflect genotoxic stress leading to stunted growth, as supported by earlier studies in tomato and other crops (Mensah *et al.*, 2006; Khan & Goyal, 2009).

Canopy volume:

Canopy volume differed significantly among EMS treatments at all stages except 35 DAS. The 0.5% EMS treatment exhibited the largest volumes $1.08 \times 10^{-5} \text{ m}^3$ (14 DAS), $6.48 \times 10^{-5} \text{ m}^3$ (21 DAS), $2.14 \times 10^{-4} \text{ m}^3$ (28 DAS) and $9.13 \times 10^{-4} \text{ m}^3$ (42 DAS). The control and higher EMS doses showed progressively smaller volumes, with the 1.5% EMS treatment recording the lowest values at each stage: $3.24 \times 10^{-6} \text{ m}^3$, $1.83 \times 10^{-5} \text{ m}^3$, $8.65 \times 10^{-5} \text{ m}^3$, and $4.88 \times 10^{-4} \text{ m}^3$, respectively (Table 2).

Table 2: Effect of Variety on the Germination and Growth Contributing Parameters

Treatment	Plumule Length (cm)			Radicle Length (cm)			Root Length (cm)				
	3 DAS	5 DAS	7 DAS	3 DAS	5 DAS	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS
T ₀	0.9ab	1.7b	2.8ab	1.15a	2.06a	2.95ab	1.6ab	2.86ab	4.11ab	6.1a	8.28a
T ₁	1.11a	2.28a	3.23a	1.31a	2.4a	3.28a	1.76a	3.11a	4.33a	6.13a	8.68a
T ₂	0.75b	1.78b	2.61ab	1.08a	1.86a	2.5bc	1.26b	2.05ab	3.25b	4.55b	7.6a
T ₃	0.63b	1.5b	2.38b	0.86a	1.9a	2.1c	1.23b	1.95b	3.4ab	5.46ab	7.5a
Level of significance	**	**	**	NS	NS	**	**	**	**	**	NS
CV%	23.27	12.48	16.09	27.0	17.94	14.78	18.31	25.78	15.01	15.41	10.44
LSD(0.05)	0.33	0.38	0.74	0.5	0.62	0.67	0.45	1.08	0.95	1.43	1.40
Treatment	Plant Height (cm)						Canopy Volume (m ³)				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS
T ₀	2.66a	4.71a	6.51a	7.36ab	9.83a	11.58a	$7.86\text{E-}6 \text{ b}$	$3.97\text{E-}5 \text{ b}$	$1.62\text{E-}4 \text{ b}$	$2.92\text{E-}4 \text{ a}$	$6.76\text{E-}4 \text{ b}$
T ₁	2.95a	4.73a	6.51a	7.95a	9.86a	11.71a	$1.08\text{E-}5 \text{ a}$	$6.48\text{E-}5 \text{ a}$	$2.14\text{E-}4 \text{ a}$	$3.98\text{E-}4 \text{ a}$	$9.13\text{E-}4 \text{ a}$
T ₂	2.81a	4.43ab	5.48b	6.93ab	8.9a	10.61a	$4.91\text{E-}6 \text{ c}$	$2.96\text{E-}5 \text{ bc}$	$1.29\text{E-}4 \text{ b}$	$2.73\text{E-}4 \text{ a}$	$5.25\text{E-}4 \text{ b}$
T ₃	2.13b	3.83b	5.18b	6.48b	8.28a	11.67a	$3.24\text{E-}6 \text{ c}$	$1.83\text{E-}5 \text{ c}$	$8.65\text{E-}5 \text{ c}$	$1.33\text{E-}3 \text{ a}$	$4.88\text{E-}4 \text{ b}$

Level of significance	*	**	**	**	NS	NS	**	**	**	NS	**
CV%	10.65	10.23	9.85	10.63	13.02	12.57	17.04	24.69	15.07	222.81	17.25
LSD (0.05)	0.47	0.76	0.97	1.28	2.01	2.40	1.91E-6	1.57E-5	3.74E-5	1.93E-3	1.88E-4

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 5% level of probability, NS = Not Significant, T₀ = Control, T₁ = EMS Dose 0.5 %, T₂ = EMS Dose 1 %, T₃ = EMS Dose 1.5 % and DAS = Days after sowing

Interaction Effect of Variety and EMS

The interaction between tomato variety and EMS treatment showed a significant influence on nearly all observed traits, including germination percentage, plumule length, root length, number of roots and leaves per plant, plant height, and canopy volume.

Germination percentage:

The interaction between variety and EMS treatment had a significant effect on germination percentage at all observation stages. The maximum germination (74.00%, 93.33%, and 98.00%) was observed in the combination BARI Tomato-12 × 0.5% EMS, while the lowest germination (20.00%, 32.00%, and 34.67%) was recorded in BARI Tomato-18 × 1.5% EMS at 3, 5, and 7 DAS, **respectively (Table 3)**. This suggests that BARI Tomato-12 responded more positively to 0.5% EMS, while BARI Tomato-18 was more sensitive to higher EMS levels. The interaction clearly indicates that both genetic background and EMS concentration jointly influence germination potential in tomato seeds

Plumule length:

The interaction between variety and EMS treatment had a significant effect on plumule length at 3, 5, and 7 DAS. The highest plumule lengths (1.46 cm, 2.93 cm, and 4.10 cm) were observed in the combination BARI Tomato-12 × 0.5% EMS, whereas the shortest plumules (0.60 cm, 1.33 cm, and 2.33 cm) were recorded in BARI Tomato-18 × 1.5% EMS across the three time **points (Table 3)**. This indicates a positive synergistic effect of genotype and optimal EMS dose, suggesting that BARI Tomato-12 possesses greater mutagenic tolerance and may benefit from induced genetic variation at low EMS levels. Similar genotype-treatment interactions have been reported in tomato by Wani *et al.* (2011), where certain cultivars responded favorably to low EMS doses with enhanced vigor and seedling growth.

Radicle length:

The interaction between variety and EMS treatment had a significant effect on radicle length at 7 DAS. The maximum root length (3.80 cm) was recorded in the combination BARI Tomato-12 × 0.5% EMS, while the minimum root length (2.10 cm) was found in BARI Tomato-18 × 1.5% EMS. Although both varieties responded positively to the 0.5% EMS treatment, BARI Tomato-12 showed a more pronounced response. Conversely, BARI Tomato-18 exhibited greater sensitivity at higher EMS doses, resulting in reduced root growth **(Table 3)**.

Root length:

The interaction effects between tomato varieties and treatments on root length were evaluated at multiple intervals after sowing. No significant differences were observed at 14 and 21 days after sowing (DAS). However, at 28 DAS, the interaction showed significant differences, with BARI Tomato-12 under treatment 0.5% EMS exhibiting the highest root length (4.4 cm), outperforming BARI TOMATO-18×1.5% EMS which showed the lowest root length (2.7 cm). At

42 DAS, a significant interaction effect was again observed, where BARI TOMATO-12×0.5% recorded the greatest root length (9.4 cm), while BARI TOMATO-18×1.5% EMS had the smallest (6.86 cm) **(Table 3)**.

Number of roots per plant:

The interaction between variety and EMS treatment had a significant effect on number of roots per plant from 14 DAS onward. The highest number of roots per plant was recorded in the combination BARI Tomato-12 × 0.5% EMS, with values of 3.0 (14 DAS), 10.33 (21 DAS), 14.67 (28 DAS), 32.0 (35 DAS), and 36.0 (42 DAS). The lowest number of roots was found in BARI Tomato-18 × 1.5% EMS at all stages **(Table 3)**.

Number of leaves per plant:

The interaction between variety and EMS treatment significantly affected the number of leaves per plant at 7, 35, and 42 DAS. The highest number of leaves per plant was recorded in BARI Tomato-12 × 0.5%

EMS, with values of 2.0 (7 DAS), 12.0 (35 DAS), and 17.0 (42 DAS). The lowest number of leaves was recorded in BARI Tomato-18 × 1.5% EMS at 7 DAS (0.0) and remained among the lowest across all other stages (**Table 3**).

Plant height:

The interaction between variety and EMS treatment significantly affected plant height at all stages. The maximum plant height was recorded in BARI Tomato-12 × 0.5% EMS, with values of 5.70 cm (14 DAS), 7.87 cm (21 DAS), 9.40 cm (28 DAS), 12.03 cm (35 DAS), and 13.73 cm (42 DAS). The lowest plant height was recorded in BARI Tomato-18 × 1.5% EMS at all stages, with 3.43 cm (14 DAS), 4.66 cm (21 DAS), 6.50 cm (28 DAS), 8.13 cm (35 DAS), and 10.5 cm (42 DAS) (**Table 4**). According to Khan and Goyal (2009), such negative effects at higher EMS concentrations are often due to severe chromosomal damage, leading to impaired cell division, poor organ development, and reduced vigor.

Canopy volume:

The interaction between variety and EMS treatment significantly influenced canopy volume at all stages except 35 DAS. The combination BARI Tomato-12 × 0.5% EMS yielded the highest volumes by $1.66 \times 10^{-5} \text{ m}^3$ (14 DAS), $9.95 \times 10^{-5} \text{ m}^3$ (21 DAS), $2.98 \times 10^{-4} \text{ m}^3$ (28 DAS), and $1.39 \times 10^{-3} \text{ m}^3$ (42 DAS) respectively. The lowest volumes were recorded in BARI Tomato-18 × 1.5% EMS at the same stages by $2.78 \times 10^{-6} \text{ m}^3$, $1.51 \times 10^{-5} \text{ m}^3$, $7.44 \times 10^{-5} \text{ m}^3$, and $3.82 \times 10^{-4} \text{ m}^3$, respectively (**Table 4**).

Table 3: Effect of the Interaction of Variety and Treatment on the Germination and Growth Contributing Parameters

Interaction	Germination (%)			Plumule Length (cm)			Radicle Length (cm)			Root length(cm)				
	3 DAS	5 DAS	7 DAS	3 DAS	5 DAS	7 DAS	3 DAS	5 DAS	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS
V1T0	64.0a	74.33ab	84.33ab	1.2ab	2.06b	3.16ab	1.26a	2.0a	2.96ab	1.76a	3.3a	4.23ab	6.16a	8.4ab
V1T1	74.0a	93.33a	98.0a	1.46a	2.93a	4.1a	1.46a	2.63a	3.8a	1.83a	2.86a	4.4a	5.9a	9.4a
V1T2	27.33bcd	30.33c	55.67bc	0.87bc	2.23b	2.9ab	1.2a	2.06a	2.86ab	1.36a	2.5a	3.67ab	5.0a	8.16ab
V1T3	35.33b	18.0c	30.0c	0.63bc	1.67bc	2.43b	0.8a	1.6a	2.2b	1.3a	2.23a	4.06ab	6.53a	8.13ab
V2T0	21.33cd	70.67ab	84.33ab	0.6c	1.33c	2.43b	1.16a	2.13a	2.93ab	1.43a	2.93a	4.03b	6.03a	8.10ab
V2T1	20.0d	68.67ab	85.33ab	0.76bc	1.63bc	2.36b	0.97a	2.16a	2.76ab	1.7a	2.86a	4.2ab	6.36a	7.96ab
V2T2	32.0bc	42.67bc	59.33cc	0.63bc	1.33c	2.33b	0.96a	1.67a	2.23b	1.16a	1.6a	2.9ab	4.4a	7.03ab
V2T3	20.67d	32.0c	34.67c	0.63bc	1.33c	2.33b	0.93a	2.2a	2.13b	1.16a	1.67a	2.7b	4.1a	6.86b
Level of significance	**	**	**	**	**	**	NS	NS	**	NS	NS	**	NS	**
CV%	10.17	20.53	18.89	23.27	12.48	16.09	27.0	17.94	14.78	18.31	25.78	15.01	15.41	10.44
LSD(0.05)	10.78	31.77	36.14	0.59	0.65	1.27	0.32	1.06	1.16	0.77	1.85	1.63		2.41

Variety	Number of Roots Plant ⁻¹						Number of Leaves Plant ⁻¹					
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS
V1T0	1.33a	2.33ab	6.67b	13.0ab	19.33b	32.0ab	2.0a	2.33a	4.0a	6.0a	10.67ab	13.67abc
V1T1	1.33a	3.0a	10.33a	14.67a	32.0a	36.0a	2.0a	2.67a	5.33a	7.0a	12.0a	17.0a
V1T2	1.0a	2.0ab	7.33ab	11.67bc	17.0bc	25.0bc	0b	1.33a	4.0a	7.0a	8.66ab	13.33abc
V1T3	1.0a	1.67ab	5.00b	10.67bcd	15.c76	24.67bc	0b	2.0a	4.0a	6.33a	8.0b	12.0c
V2T0	1.33a	1.67ab	50.b	8.33de	14.33cd	22.67cd	0.67b	1.0a	3.67a	7.0a	10.0ab	14.33abc
V2T1	1.0a	2.0ab	6.33b	10.0cde	14.33cd	24.33bc	0.0b	2.0a	4.66a	8.33a	11.0ab	16.67ab
V2T2	1.0a	1.67ab	5.33b	7.33e	11.33de	15.33d	0.33b	2.33a	4.0a	7.0a	7.33b	12.67bc
V2T3	1.0a	1.0b	4.67b	7.67e	10.67e	18.0cd	0.0b	2.0a	4.0a	6.33a	8.0b	13.67abc
Level of significance	NS	**	**	**	**	**	**	NS	NS	NS	**	**
CV%	31.43	35.78	19.30	9.22	6.73	10.99	68.73	35.02	16.91	17.81	13.96	10.14
LSD(0.05)	1.08	1.97	3.52	2.76	3.04	7.83	1.23	1.97	2.13	3.52	3.80	4.13

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 5% level of probability, NS = Not significant, V1 = BARI Tomato-12, V2 = BARI Tomato-18, T0 = Control, T1 = EMS Dose 0.5 %, T2 = EMS Dose 1 %, T3 = EMS Dose 1.5 % and DAS= Days After sowing

Table 4: Effect of the Interaction of Variety and Treatment on the Germination and Growth Contributing Parameters

Variety	Plant Height (cm)						Canopy Volume (m ³)				
	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS
V1T0	2.9abc	5.06ab	6.9ab	7.16b	10.1ab	12.3ab	1.07E ⁻⁵ b	4.86E ⁻⁵ b	1.93E ⁻⁴ b	3.88E ⁻⁴ a	8.29E ⁻⁴ b
V1T1	3.56a	5.7a	7.87a	9.4a	12.03a	13.73a	1.66E ⁻⁵ a	9.95E ⁻⁵ a	2.98E ⁻⁴ a	6.17E ⁻⁴ a	1.39E ⁻³ a
V1T2	3.13ab	2.9abc	5.4bc	7.03b	8.96ab	9.46b	5.24E ⁻⁶ c	3.63E ⁻⁵ bc	1.47E ⁻⁴ bc	3.6E ⁻⁴ a	5.2E ⁻⁴ bc
V1T3	2.23c	4.23bcd	5.7bc	6.46b	8.43b	9.43b	3.71E ⁻⁶ c	2.15E ⁻⁵ c	9.86E ⁻⁵ cd	2.08E ⁻³ a	5.95E ⁻⁴ bc
V2T0	2.43bc	4.4bcd	6.13bc	7.56ab	9.56ab	11.13ab	5.02E ⁻⁶ c	3.08E ⁻⁵ bc	1.31E ⁻⁴ bcd	1.96E ⁻⁴ a	5.22E ⁻⁴ bc
V2T1	2.33bc	3.7cd	5.16c	6.5b	7.7b	9.43b	4.89E ⁻⁶ c	3.0E ⁻⁵ bc	1.29E ⁻⁴ bcd	1.8E ⁻⁴ a	4.4E ⁻⁴ c
V2T2	2.5bc	3.97bcd	5.56bc	6.83b	8.83ab	11.76ab	4.57E ⁻⁶ c	2.95E ⁻⁵ bc	1.1E ⁻⁴ cd	1.86E ⁻⁴ a	5.29E ⁻⁴ bc
V2T3	2.13c	3.43d	4.66c	6.5b	8.13b	10.5ab	2.78E ⁻⁶ c	1.51E ⁻⁵ c	7.44E ⁻⁵ d	1.39E ⁻⁴ a	3.82E ⁻⁴ c
Level of significance	**	**	**	**	**	**	**	**	**	NS	**
CV%	10.65	10.23	9.85	10.63	13.02	12.57	17.04	24.69	15.07	222.81	17.25
LSD(0.05)	0.81	1.30	1.68	2.19	3.45	4.12	3.28E ⁻⁶	2.7E ⁻⁵	6.41E ⁻⁵	3.32E ⁻³	3.23E ⁻⁴

In a column, figures with the same letter do not differ significantly as per DMRT. ** = Significant at 5% level of probability, NS = Not significant, V1 = BARI Tomato-12, V2 = BARI Tomato-18, T0 = Control, and DAS= Days After sowing

IV. Conclusion

The present investigation entitled “Effect of Different Doses of Ethyl Methane Sulphonate (EMS) on Germination and Growth Attributes of Two Tomato Varieties” was conducted at the Tissue Culture Laboratory, Horticulture Division, Bangladesh Institute of Nuclear Agriculture (BINA), Mymensingh, during the period from October 2024 to December 2024 with the objectives of selecting the suitable tomato variety, determining the most effective EMS dose in relation to germination and early growth, and assessing the interaction effect of variety and EMS concentration on seedling performance. The experiment followed a Completely Randomized Design (CRD) with three replications and

included two tomato varieties—BARI Tomato-12 and BARI Tomato-18—and four EMS treatments: Control (0%), EMS 0.5%, EMS 1%, and EMS 1.5%. Data were recorded on germination percentage, plumule length, root length, number of roots and leaves per plant, plant height, and canopy volume across multiple growth stages. Significant variation was observed across all main factors and their interaction. BARI Tomato-12 showed consistently superior performance compared to BARI Tomato-18 across all traits, reflecting its greater genetic potential and tolerance to EMS-induced stress. Among the EMS concentrations, 0.5% EMS significantly enhanced germination, shoot and root growth, leaf production, and canopy development, whereas higher concentrations (1% and 1.5%) caused inhibitory effects likely due to mutagenic toxicity. The interaction effect revealed that the combination of BARI Tomato-12 treated with 0.5% EMS was the most effective, achieving the highest germination (98.0%), longest plumule (4.1 cm), tallest plants (13.73 cm), and largest canopy volume (1.39E-3 m³), indicating strong early seedling vigor. In contrast, BARI Tomato-18 treated with 1.5% EMS showed the poorest performance, confirming its greater sensitivity to EMS stress. Overall, the study demonstrates that EMS has a concentration-dependent impact on tomato development, where 0.5% EMS is optimal and BARI Tomato-12 is the most responsive genotype. This combination

(BARI Tomato-12 × EMS 0.5%) holds strong potential for future mutation breeding programs aimed at enhancing germination, early growth, and overall seedling vigor in tomato. Further molecular and field-based studies are recommended to validate these findings and develop genetically stable, high-performing EMS-induced tomato lines suitable for diverse agro-ecological conditions in Bangladesh.

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