
The Germination and Growth Responses of Tomato (*Solanum lycopersicum*) Seeds in Various In Vitro Culture Media

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Abstract

Tomatoes (*Solanum lycopersicum* L.) are an important horticultural crop with steadily increasing demand in Indonesia, yet their productivity often fluctuates. The availability of high-quality seeds, including those produced through in vitro propagation techniques, is a key factor in producing vigorous and uniform seedlings. The study employed a factorial Complete Randomized Design with two treatments. The aimed to compare the germination and early growth responses of two tomato varieties, MicroTom and MT3, on six different culture media: Full-MS, Half-MS, Full-MS+GA₃ 0.5 mg/L, Chu's N₆, Chu's N₆+GA₃ 0.5 mg/L, and Gamborg B₅. The results showed that the culture medium had a significant effect on all parameters, while the variety had a significant effect only on the average germination time and shoot length. The Half-MS, Chu's N₆, and Gamborg B₅ media yielded the highest germination rates (70–72%), while Full-MS produced the lowest rate (35%). MT3 exhibited a faster germination rate (6.91 days) and longer shoot length (34.41 mm) compared to MicroTom. The longest root length was observed in the MT3 grown on Half-MS (C₂M₂), and the longest shoot length was observed in the MT3 grown on Gamborg B₅ (C₂M₆). GA₃ supplementation did not always enhance vigor or early growth. The interaction between variety and medium had a significant effect, particularly on root and shoot growth. This indicates that the effectiveness of the medium depends on the genotype used. Overall, Half-MS, Chu's N₆, and Gamborg B₅ are recommended as optimal media for tomato germination and early growth, particularly for the MT3.

Keywords: Culture media, GA₃, seedlings, variety, vigor.

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INTRODUCTION

One of the most widely grown horticultural crops in Indonesia is the tomato (*Solanum lycopersicum* L.). Tomatoes have a unique flavor—a combination of sweet and sour. Typically, tomatoes can be eaten fresh or processed industrially or at home (Rahayu & Murti, 2020). Their high nutritional value and strong market prospects make tomatoes one of the top agricultural commodities. Tomato yields vary from year to year, and in Indonesia, they are considered to be highly volatile. According to data from the Central Statistics Agency, Indonesia's tomato production in 2021 was 1,114,399 tons, increasing to 1,168,744 tons

in 2022, but dropping to 1,143,788 tons in 2023 (Badan Pusat Statistik, 2023). As Indonesia's population grows, this will lead to a continuous increase in demand for tomatoes. The availability of high-yielding, high-quality tomato varieties will help meet this high demand (Syukur et al., 2015). Badan Pusat Statistik (2023) reports variations in tomato production in North Sumatra. In 2021, production reached 203,162 tons, but in 2022 it fell to 183,015 tons, a decrease of approximately 9.91% from the previous year. However, in 2023, production increased again to 203,868 tons, nearly matching the 2021 level. Due to high production risks, tomato production has declined and fluctuated. Tomato farmers frequently face threats such as diseases and pests, as well as unfavorable climate changes (Marleni et al., 2025).

Other contributing factors, such as the quality of the seeds used, influence efforts to improve the quality and quantity of tomato production in order to meet customer demand. The availability of varieties suited to the local environment and with high yield potential are factors that directly influence yield and the varieties' adaptability to the environment (Tarigan et al., 2023). Seeds that lack good viability and vigor will result in suboptimal early growth, which affects crop performance through the generative phase. The genetic, physiological, and physical qualities of seeds can determine the quality of the yield. Crops will produce high-quality yields and high production levels if high-quality seeds are available to farmers. As the planting material, seeds determine the initial success of the production process, starting with germination before a seed can develop into a plant (Lestari, 2024). Most researchers conduct studies on plant physiology, genetics, and tissue culture using small tomato varieties such as MicroTom. Micro-Tom is favored by researchers because of its short life cycle (70–90 days) and small size, approximately 10–20 cm, making it a practical plant well-suited to represent research on tomato plants or other plants in the Solanaceae family, as well as for laboratory research (Arum, 2021).

Tomato-3 (MT3) is a high-yielding variety developed by MARDI (the Malaysian Agricultural Research and Development Institute) for cultivation in tropical lowlands. MT3 has demonstrated impressive field performance in warm climates; however, seedling production via tissue culture remains a challenge, and its response to tissue culture has not yet been documented. Meanwhile, MicroTom has been tested under *in vitro* conditions and has yielded good results. In the absence of specific guidelines for this genotype, researchers can adopt the MicroTom protocol to address factors that hinder germination efficiency and seedling viability in MT3. The MT3 variety was developed to reduce extensive farming practices in highland areas and is capable of meeting the increasing local demand for tomatoes (Saat et al., 2022).

In vitro propagation is a method used to improve seed germination success. One way to obtain healthy, disease-free tomato seedlings is through tissue culture techniques. *In vitro* techniques are used to develop plants in tissue culture that will pass on the same traits to their offspring as their parent plants. *In vitro* is defined as the activity of maintaining and growing plant tissues (callus, cells, protoplasts) and organs (leaves, apical/lateral shoots, stems, roots, and embryos) under aseptic conditions. Compared to conventional methods, *in vitro* propagation also offers advantages in terms of faster seedling growth and a higher level of seedling uniformity. Large-scale tomato production can be achieved quickly through seedling propagation via tissue culture (Prasetyo et al., 2022). The success of tissue culture requires several supporting conditions, including the use of the appropriate medium and aseptic environmental conditions (Rahmawati, 2021).

One of the key factors influencing the success of plant seedling propagation using tissue culture is the type of medium used. Tissue culture media can vary widely, such as BAP (Benzyl Amino Purine), MS (Murashige and Skoog), IAA (Indole Acetic Acid), and so on, or they may be a combination of these types of media (Prasetyo et al., 2022). The composition of the culture medium (basal medium), carbon source, and other environmental factors are critical to the successful *in vitro* germination of tomato seeds. The type of medium—or combination of media—used will determine the light intensity required.

Light intensity is crucial for photosynthesis and plant growth. Optimal light conditions support hypocotyl and radicle growth as well as germination, while modifications to the growing medium—including adjustments to macro- and microelement levels, hormones, and sucrose—also enhance growth synchronization (Wei et al., 2023). Efforts to improve seed germination through the use of small amounts of plant growth regulators. Non-nutrient organic compounds known as plant growth regulators (PGRs) have the ability to stimulate, inhibit, and regulate physiological processes in plants (Kurnianingrum & Rosya, 2024). GA₃ is a type of gibberellin plant growth regulator that influences plant development processes, including germination, cell elongation, flowering, fruit set, and seed formation. Additionally, gibberellins can break seed dormancy by acting as a substitute for low temperatures, long daylength, and infrared radiation (Alfiani, 2019).

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By comparing germination rates, we can make predictions about future production results, average germination times, and seedling vigor indices between MT3 and MicroTom on six culture media: full-dose MS, half-dose MS, Chu's N6, Gamborg's B5, MS supplemented with 0.5 mg/L GA₃, and N6 supplemented with 0.5 mg/L GA₃. The findings aim to establish genotype-specific recommendations, improve resource efficiency, produce high-quality and uniform seedlings, and support fundamental research as well as commercial propagation efforts.

MATERIALS AND METHODS

Place and Time

The study was conducted at the Microbial Taxonomy Laboratory in the Biotechnology and Nanotechnology Research Center (BN) building of the Malaysian Agriculture Research and Development Institute (MARDI) in Serdang, Selangor, Malaysia, from September 21 to October 10, 2025.

Materials and Tools

The materials used were MT3 and MikroTom tomato seeds, MS basal salts (Murashige & Skoog Medium), sucrose, Gelrite, distilled water (dH₂O), NaOH, HCl, GA₃, Chu's N6 basal medium, Gamborg B₅ basal salts, Clorodengan, and ethanol.

The equipment used includes gloves, an autoclave, 500-ml Durán bottles, a measuring cylinder, a laminar air flow hood, an Eppendorf Research Plus micropipette, white anti-static plastic containers, a magnetic stir bar retriever, a laboratory spatula, petri dishes, tweezers, writing utensils, scissors, masking tape, parafilm, tissues, test tube rack, analytical balance, pipette tips, pH meter, hotplate stirrer, spray bottle, centrifuge tubes, microscope, filter paper, laboratory gas.

Research Methods

The research design used was a completely randomized design (CRD) with two factors: variety and culture medium. The variety factors were MicroTom (C₁) and s MT3 (C₂). The culture medium factors consisted of: Full-MS (M₁), Half-MS (M₂), Full-MS+GA₃ (M₃), Chu's N₆ (M₄), Chu's N₆+GA₃ (M₅), and Gamborg B₅ (M₆).

Each factor was replicated twice. The parameters observed for the germination response test were total germination, average germination time, root length, shoot length, and vigor.

Media Preparation

Preparation of Full-MS medium (M₁) using 2.2 g of MS basal salts, 15 g of sucrose, and 2 g of Gelrite, with distilled water added to a total volume of 500 mL. Full-MS+GA₃ medium (M₂) using 2.2 g of MS basal salts, 15 g of sucrose, 2 g of Gelrite, and 0.5 mg/L of GA₃. Half-MS medium (M₃) using 1.1 g of MS basal salts, 15 g of sucrose, and 2 g of Gelrite. Chu's N₆ Medium (M₄) containing 2.0 g of Chu's N₆ basal mix, 10 g of sucrose, and 2 g of Gelrite. Chu's N₆+GA₃ Medium (M₅) containing 2.0 g of Chu's N₆ basal mix, 10 g of sucrose, 2 g of Gelrite, and 0.5 mg/L of GA₃. Gamborg B₅ medium (M₆) containing 1.6 g Gamborg B₅ basal salts, 10 g sucrose, and 2 g Gelrite. Each medium was prepared in a volume of 500 mL; all media had a pH of 5.8.

Seed Culture Preparation

MicroTom and MT3 tomato seeds were first sterilized using 70% ethanol by soaking them for 2 minutes, then rinsed with dH₂O, followed by soaking the seeds in a 20% chlorine solution for 15 minutes. They were then rinsed with dH₂O and dried on a petri dish lined with tissue paper. Media sterilization is a critical process, as prepared media often still contain a significant number of microorganisms (Sulistiani et al., 2025). Tomato seeds of the MT3 and MicroTom cultivars were cultured in Full-MS medium, Full-MS+GA₃ medium, Half-MS medium, N₆ medium, N₆+GA₃ medium, and Gamborg B₅ medium, which had been poured into culture dishes; each type of medium was used in four dishes. Each dish containing the MicroTom cultivar held 30 tomato seeds, while each dish containing the MT3 cultivar held 30 tomato seeds.

Data Analysis

Data analysis was performed using Univariate Analysis of Variance with SPSS version 24 and Microsoft Excel 2013.

RESULTS AND DISCUSSION

Germination and early growth of tomato seedlings (*Solanum lycopersicum* L.) are critical phases that significantly determine the success of plant growth in subsequent stages. Recent studies indicate that the composition of the growing medium plays a crucial role in regulating water availability, nutrient balance, and the physiological condition of the embryo during the germination process. Media with lower salt content tend to support optimal water imbibition and accelerate the activation of early seed metabolism, thereby increasing germination rates and speed.

Various studies have shown that successful germination and early seedling growth result from the interaction between growing medium factors, hormonal treatments, and the genetic response of the variety. Selecting the appropriate medium and using suitable growth regulators are key strategies for producing high-quality tomato seedlings with strong growth potential. The results of growth parameter observations are presented in the following table.

Germination Rate of Tomato Seeds

The MikroTom and MT3 varieties showed no significant difference in total germination percentage. The average germination percentage of the two varieties were relatively similar, at 58.66% for MikroTom and 58.75% for MT3. This MikroTom and MT3 varieties showed no significant difference in total germination percentage. The average germination percentages for both varieties were relatively similar, at 58.66% for MikroTom and 58.75% for MT3. This indicates that the seed's basic germination ability is determined more by the variety's genetics than by environmental factors such as the growing medium's condition, but the combination of culture media and variety resulted in a significant difference in germination percentage. The analysis of germination percentages is presented in Table 1.

Table 1. Total Germination of MikroTom and MT3 Tomato Seeds on Various Media (%).

	C ₁ (MikroTom)	C ₂ (MT3)	Media Average
M ₁ (Full-MS)	29.70 _e	41.25 _{de}	35.48
M ₂ (Half-MS)	77.82 _a	65.00 _{abc}	71.41
M ₃ (Full-MS+GA ₃)	42.50 _{cde}	48.75 _{bcde}	45.63
M ₄ (Chu's N ₆)	75.27 _a	65.00 _{abc}	70.14
M ₅ (Chu's N ₆ +GA ₃)	60.00 _{abcd}	55.00 _{abcd}	57.50
M ₆ (Gamborg B ₅)	66.67 _{ab}	77.50 _a	72.08
Variety Average	58.66	58.75	

Note: Numbers followed by different letters indicate significant differences in the DMRT (P<0.05).

As shown in Table 1, the culture medium had no significant effect on the total germination of tomato seeds. The MikroTom variety grown on Half-MS medium (C₁M₂, C₁M₄, and C₂M₆) produced significantly higher germination rates compared to MikroTom grown on Full-MS and Full-MS+GA₃ medium (C₁M₁ and C₁M₃). Additionally, there was a significant difference compared to the MT3 variety grown in Full-MS and Full-MS+GA₃ media (C₂M₁, C₂M₃).

The highest germination rate was observed in the MikroTom variety grown in Half-MS medium (77.82%), while the lowest was in MikroTom grown in Full-MS medium. Reducing the salt concentration in the medium can facilitate imbibition, reduce ionic stress, increase enzyme activity, and maintain the physiological balance of the seeds; this significantly improves the germination capacity of MikroTom (Ellouzi et al., 2024). Thus, for both C₁ and C₂, media with lower salt concentrations or a more balanced nitrogen composition provide more optimal conditions for germination.

The difference in germination rates indicates that media with lower salt concentrations are able to reduce osmotic pressure, accelerate imbibition, and activate embryo metabolism more efficiently. The ion and nitrogen balance in these media supports the activity of hydrolytic enzymes during the early stages of germination. The combination of MikroTom and Half-MS (C₁M₂), MT3 and Gamborg B₅ (C₂M₆) is more recommended for improving total germination compared to C₁M₁ and C₂M₁ because it provides more stable physiological conditions and supports seed viability.

Media with lower salt concentrations (e.g., Half-MS) have proven to be more effective for germination because they lower osmotic pressure and accelerate water uptake, thereby enhancing embryo metabolic activation (Nurchayati, 2023). Media with a more balanced organic nitrogen content,

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such as B₅, enhance the activity of enzymes involved in early germination and embryo respiration (Sidik et al., 2024). High levels of ammonium ions (NH₄⁺) in concentrated media can reduce germination viability by disrupting the embryo's internal pH balance (Song et al., 2022). This explains why the M₆, M₂, and M₄ media yielded the highest germination rates, while the MS medium with high salt concentration yielded the lowest percentage.

A study conducted by Shintiavira et al. (2024) shows that variations in culture medium composition have a significant effect on the germination rate and early growth of horticultural plants. Media with a good balance of nutrients have been shown to improve seedling quality, particularly during the early stages of vegetative growth. These findings are consistent with research showing that Half-MS, Chu's N₆, and Gamborg B₅ media yield better germination responses compared to Full-MS media.

Tomato Seed Germination Time

The combination of variety and growing medium treatments showed a significant interaction effect on the germination rate (Mean Germination Time = MGT) of tomato seeds. However, the variety and growing medium treatments alone had no significant effect on the germination time of tomato seeds. Differences in tomato seed germination time due to variety and growing medium treatments can be seen in Table 2.

Table 2. Germination time of tomato seeds in various growing media (days).

	C ₁ (MikroTom)	C ₂ (MT3)	Media Average
M ₁ (Full-MS)	7.27 _{abcd}	7.27 _{abcd}	7.27
M ₂ (Half-MS)	7.35 _{abcd}	6.63 _{cd}	6.99
M ₃ (Full-MS+GA ₃)	8.14 _a	7.49 _{ab}	7.81
M ₄ (Chu's N ₆)	6.75 _{cd}	6.75 _{cd}	6.75
M ₅ (Chu's N ₆ +GA ₃)	7.85 _{ab}	6.96 _{bcd}	7.40
M ₆ (Gamborg B ₅)	7.39 _{abcd}	6.37 _d	6.88
Variety Average	7.46	6.91	

Note: Numbers followed by different letters indicate significant differences in the DMRT (P<0.05).

As shown in Table 2, the MT3 variety grown on Gamborg B₅ (C₂M₆) medium exhibited significantly faster germination times compared to MikroTom germinated on Full-MS+GA₃ and Chu's N₆+GA₃ media, as well as MT3 on Full-MS+GA₃ and Chu's N₆ media. The average MGT for MT3 was 6.91 days, while that for MikroTom was 7.46 days. This indicates that MT3 has more efficient early metabolic activity compared to MikroTom. The germination of MikroTom and MT3 tomato seeds can be seen in Figure 1.

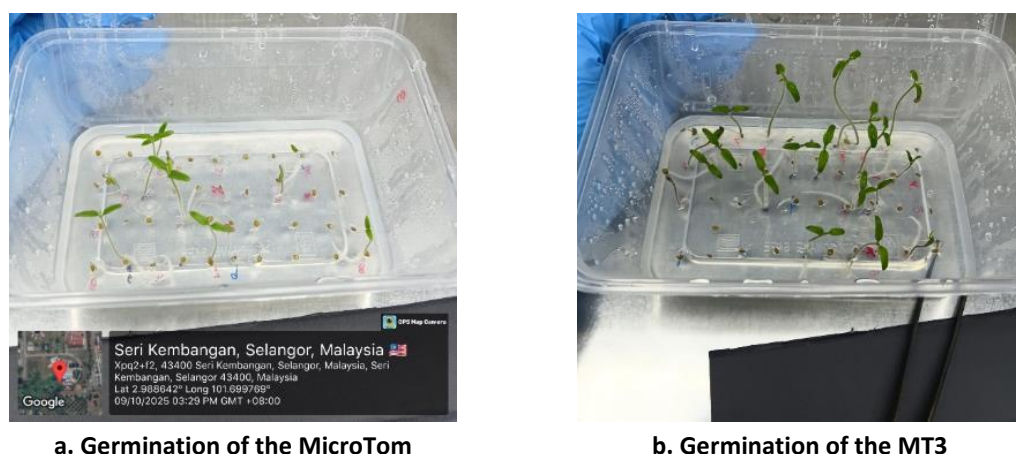


Figure 1. Germination of MikroTom (a) and MT3 (b) Tomato Seed Varieties.

The MikroTom variety showed the fastest germination time on Chu's N₆ (C₁M₄) medium, at 6.75 days. Its germination time was significantly faster than that of C₁M₃ (8.14 days). The MT3 variety grown on Chu's N₆ medium showed the fastest germination time (6.37 days), and this differed significantly from that on Gamborg B₅ (C₂M₄) at 6.75 days and on C₂M₃ (7.49 days). Full MS+GA₃ medium consistently slowed

germination in both varieties. The MicroTom variety grown on Chu's N₆ medium (C₁M₄) produced the fastest germination time and performed better than C₁M₃, which showed the longest time. Meanwhile, the C₂M₆ combination produced the fastest germination time compared to C₂M₃, which had the longest time. These differences indicate that media with lower total ion concentrations accelerate water and oxygen uptake, thereby accelerating the activation of enzymes such as α -amylase and embryo respiration.

Grossnickle & MacDonald (2018) state that seedling quality evaluation cannot be based on a single growth parameter alone. An integrated evaluation approach that includes germination percentage, germination rate (Mean Germination Time), root length, and shoot length provides a more comprehensive picture of seedling performance. This approach aligns with the analysis used in this study to assess the quality of tomato seeds in various culture media.

Media with high salt content and the addition of GA₃ tend to delay germination because they trigger physiological imbalances in the early stages. The combination of C₁M₄ and C₂M₆ is more recommended for accelerating germination time compared to C₁M₃ and C₂M₃, which may slow down radicle emergence. Germination rate is influenced by water uptake efficiency and the activation of enzymes such as α -amylase in the early stages (Njeri et al., 2019). Different varieties have genetic differences in seed coat permeability and early metabolic activity, and thus may exhibit different MGT (Zuhri et al., 2025). Media with lower total ion concentrations accelerate embryo expansion and radicle release (Mohammed & Baldwin, 2024). Therefore, M₄ and M₆ promote the fastest MGT, while M₃ (Full-MS+GA₃) slows it down due to the combined effects of high salt and hormones

Root Length of Tomato Seedlings

Variety treatments with independent growing media showed variations in physiological responses, although these were not statistically significant. In contrast, the combination of variety and growing media treatments showed significant variations in the root length of tomato seedlings. Statistically, there was no significant difference between the root lengths of MicroTom (30.37 mm) and MT3 (29.41 mm). This indicates that root growth is more influenced by the growing environment than by variety factors. Differences in root length due to variety and growing medium treatments, as well as their interactions, are presented in Table 3.

Table 3. Root Length of Tomato Seedlings in Various Media (mm).

	C ₁ (MikroTom)	C ₂ (MT3)	Media Average
M ₁ (Full-MS)	39.09 ^{ab}	27.10 ^{cd}	33.09
M ₂ (Half-MS)	43.25 ^a	46.18 ^a	44.71
M ₃ (Full-MS+GA ₃)	26.06 ^{cd}	17.76 ^{ef}	21.91
M ₄ (Chu's N ₆)	25.62 ^{cd}	29.26 ^{cd}	27.44
M ₅ (Chu's N ₆ +GA ₃)	14.97 ^f	24.09 ^{de}	19.53
M ₆ (Gamborg B ₅)	33.23 ^{bc}	32.06 ^{bcd}	32.64
Variety Average	30.37	29.41	

Note: Numbers followed by different letters indicate significant differences in the DMRT (P<0.05).

The combination of variety and culture medium treatments showed an interaction that had a significant effect on root length. The longest roots were obtained from the MT3 variety grown in Half-MS medium (C₂M₂), followed by MikroTom grown in Half-MS medium (C₁M₂) and Full-MS medium (C₁M₁), although the differences in root length were not significant. The roots formed by these three treatment combinations were significantly shorter. These results indicate that Half-MS medium consistently produced the longest roots in both varieties. Full-MS culture medium with a relatively high salt concentration inhibits growth compared to Half-MS.

According to Huang et al. (2021), growing media with high salt concentrations can inhibit root cell elongation through increased osmotic pressure and the accumulation of reactive ions. In tomato seedlings, Half-MS facilitate root elongation by increasing cell wall flexibility and promoting more stable nutrient absorption (Alatar et al., 2017). Root response to the medium is highly dependent on the interaction between genotype and environment, including nutrient composition and hormonal balance (Mehra et al., 2025). M₅ and M₃ media containing GA₃ actually produce shorter roots because external hormone concentrations can inhibit root differentiation under conditions of nutritional imbalance (Da Silva et al., 2026).

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The overall root lengths of MicroTom and MT3 differed but not significantly. There was a significant interaction between variety and medium. The longest roots were observed in the Half-MS medium (44.7 mm), while the Full-MS+GA₃ and Chu's N₆+GA₃ media produced the shortest roots (19.5–21.9 mm). MT3 exhibited longer root growth in some media compared to MicroTom. This indicates that root growth is strongly influenced by the medium, with varying effects across varieties.

Length of Tomato Seedling Shoots

The results of the data analysis indicate that there was no significant difference in the shoot length of the two tomato seedling varieties tested due to the independent effects of variety and growing medium. However, the combination of variety and growing medium treatments resulted in an interaction that had a significant effect on the length of the tomato seedlings. The differences in seedling length due to variety and growing medium treatments are presented in Table 4.

Table 4. Shoot Length of Tomato Seedlings in Various Media (mm).

	C ₁ (MikroTom)	C ₂ (MT3)	Media Average
M ₁ (Full-MS)	21.16 _{cd}	24.18 _c	22.67
M ₂ (Half-MS)	23.39 _c	38.27 _{ab}	30.83
M ₃ (Full-MS+GA ₃)	17.35 _d	25.26 _c	21.31
M ₄ (Chu's N ₆)	21.41 _{cd}	35.45 _b	28.43
M ₅ (Chu's N ₆ +GA ₃)	19.75 _{cd}	40.02 _{ab}	29.88
M ₆ (Gamborg B ₅)	23.37 _c	43.29 _a	33.33
Variety Average	21.07	34.41	

Note: Numbers followed by different letters indicate significant differences in the DMRT (P<0.05).

The MT3 variety grown on Gamborg B₅, Chu's N₆+GA₃, and Half-MS (C₂M₆, C₂M₅, and C₂M₂) media exhibited significantly longer shoot lengths compared to MicroTom grown on all tested culture media. Meanwhile, the MicroTom variety tended to have significantly shorter stems on all tested culture media. This indicates that MT3 is more sensitive to improvements in media nutrient quality, whereas MicroTom tends to exhibit stunted stem growth even on different growth media.

These results are supported by previous research showing that gibberellin (GA₃) increases stem length by activating the expansin (Expa) gene and stimulating cell wall elongation (Robil et al., 2024). Tomato varieties may have different sensitivities to gibberellins due to differences in the expression of the Della gene, which regulates the growth response (Shohat et al., 2021). A growing medium rich in vitamins and organic nitrogen (such as Gamborg B₅) enhances protein and chlorophyll synthesis, which supports sprout growth (Hamdeni et al., 2022). As a result, the combination of the responsive genotype (MT3) and growing media with balanced nutrients (M₆, M₂, M₅) produced the longest stems. The root and shoot lengths of the MicroTom and MT3 tomato varieties are shown in Figure 2.

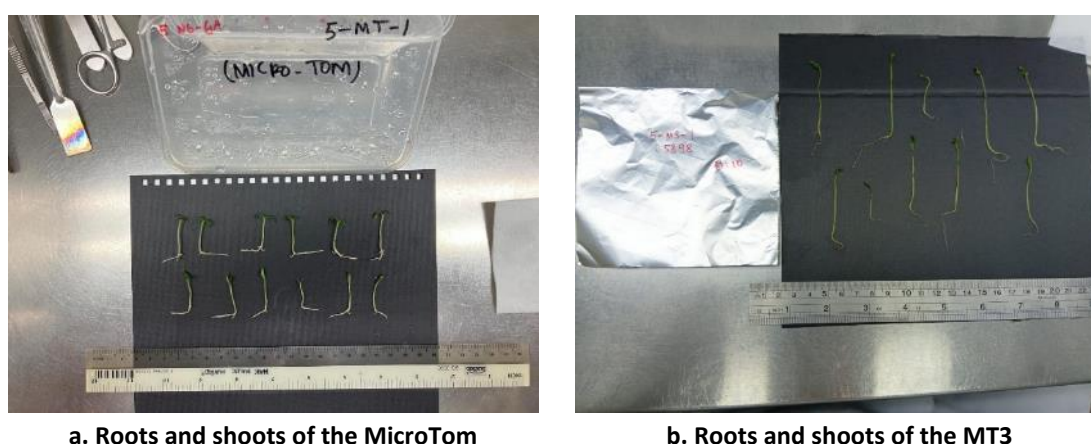


Figure 2. Root and Shoot Lengths of the MicroTom (a) and MT3 (b) Tomato Varieties.

The most obvious difference among the varieties was observed in shoot length, although it was not statistically significant. MT3 had longer shoots, averaging 34.4 mm, compared to MikroTom, which averaged only 21.1 mm. The medium also influenced shoot growth, although not significantly, with Gamborg B₅, Half-MS, and Chu's N₆+GA₃ supporting optimal growth, while Full-MS and Full-MS+GA₃ resulted in the shortest shoots. The interaction between varieties and growing media had a significant effect, where shoot growth was influenced by the combination of variety and medium. MT3 was more responsive to medium variations, producing longer shoots in nutrient-rich media.

The MikroTom and MT3 varieties did not differ significantly in final germination percentage and root length, but MT3 outperformed MikroTom in germination rate and shoot length, although the differences were not significant. The interaction between variety and growing medium had a significant effect, particularly on germination percentage, germination rate, root length, and shoot length. This indicates that the combination of variety and medium determines the maximum growth response.

Seedling Vigor Index

The tomato seedling vigor index was observed at the end of the observation period (day 10) and calculated using the formula by Abdul-Baki & Anderson (1973), which is the product of germination rate and seedling growth (shoot length). The descriptive data show differences in the growth index. A comparison of the vigor indices of the two varieties grown in various culture media is shown in Table 5.

Table 5. Tomato Seedling Vigor in Various Media (%)

	C ₁ (MikroTom)	C ₂ (MT3)	Media Average
M ₁ (Full-MS)	6.28	9.97	8.13
M ₂ (Half-MS)	18.20	24.88	21.54
M ₃ (Full-MS+GA ₃)	7.37	12.31	9.84
M ₄ (Chu's N ₆)	16.12	23.04	19.58
M ₅ (Chu's N ₆ +GA ₃)	11.85	22.01	16.93
M ₆ (Gamborg B ₅)	15.58	33.55	24.57
Variety Average	12.57	20.96	

As shown in Table 5, the MT3 variety had a significantly higher average vigor index (20.96%) compared to MikroTom (12.57%). Tomato seeds grown in different culture media also exhibited differences in seedling vigor. The highest vigor index was obtained from seeds planted in Gamborg B₅ culture medium (M₆), followed by M₂, M₄, M₅, M₃, and M₁. This indicates that culture media with lower salt content produce higher vigor indices. Culture media with high salt content, such as Full-MS (M₁), had the lowest vigor indices for both tested varieties.

Vigor is influenced by the integration of germination, root growth, shoot growth, and energy metabolism (ISTA, 2020). A medium with a good balance of organic and inorganic nitrogen increases ATP production and protein synthesis during the early stages of growth, resulting in increased vigor (Lim et al., 2021). GA₃ can increase vigor when applied in supportive nutrient conditions, but in high ionic conditions, it can cause growth imbalance (Tripathi et al., 2025).

CONCLUSION

The treatment of varieties showed no significant differences in growth for all parameters. However, the MT3 variety tended to be more responsive in terms of germination percentage, germinated faster, and produced longer shoots compared to MikroTom. The treatment of culture media also had a similar effect; however, Gamborg B₅ medium tended to promote better growth for the tested tomato seeds. The interaction between variety and culture medium produced significant differences and variations in growth across the observed parameters. The combination of variety treatment with Half-MS and Gamborg B₅ culture media yielded the highest germination rates for both MikroTom and MT3. The combination of variety treatment with Half-MS culture medium produced the longest roots for both MikroTom and MT3. The Gamborg B₅ medium combination produced significantly longer MT3 shoots and significantly faster germination times compared to MikroTom. The MikroTom and MT3 varieties, both of which are seeds, can be suitable choices for cultivation in the appropriate culture media, namely Gamborg B₅ and Half-MS.

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