

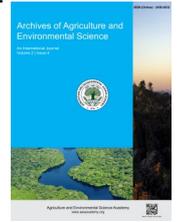


e-ISSN: 2456-6632

This content is available online at AESA

Archives of Agriculture and Environmental Science

Journal homepage: journals.aesacademy.org/index.php/aaes



ORIGINAL RESEARCH ARTICLE



## Influence of different spacing regimes on growth and productivity of BARI tomato-2

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### ARTICLE HISTORY

Received: 05 June 2025

Revised received: 23 August 2025

Accepted: 30 August 2025

### Keywords

Biological yield

Productive branch

Spacing

Tomato

### ABSTRACT

Tomato (*Solanum lycopersicum* L.) is a widely cultivated vegetable crop whose productivity is strongly influenced by its spacing and plant population. A field experiment was conducted at Rajshahi region during December, 2024 to April, 2025 to evaluate the effect of different plant spacing's ( $D_1=40 \times 45$  cm,  $D_2=50 \times 45$  cm, and  $D_3=60 \times 45$  cm) on the growth and yield of tomato (BARI Tomato -2). The experiment was laid out in a randomized complete block design (RCBD) with three replications. Healthy seedlings of BARI Tomato-2 were transplanted in well-prepared plots according to the assigned spacing treatments. Results revealed that wider spacing ( $D_3$ ) significantly enhanced vegetative and reproductive parameters compared to narrower spacings. Plants at  $D_3$  cm attained the greatest height, which was 72% higher than those grown at  $D_1$  cm. This spacing produced a higher number of primary (24%) and productive branches (62%) compared to  $D_1$ . Furthermore, proper spacing provides more fruit weight, more fruits per plant (25% more than  $D_1$ ) and increased biological yield (4.3 tha<sup>-1</sup>) compared to closed spacing. Consequently,  $D_3$  spacing achieved the highest yield (38%) per hectare, which was 26% higher than  $D_1$ . Thus, adopting an appropriate spacing (both inter and intra row) regime, particularly  $D_3$  is crucial for maximizing tomato growth and yield.

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**Citation of this article:** Irin, I. J., & Jahan, M. R. (2025). Influence of different spacing regimes on growth and productivity of BARI tomato-2. *Archives of Agriculture and Environmental Science*, 10(3), 485-489, <https://dx.doi.org/10.26832/24566632.2025.1003013>

### INTRODUCTION

Tomato (*Solanum lycopersicum* L.) is one of the most widely cultivated vegetable crops, valued for its high nutritional content and economic significance worldwide (Bhandari *et al.*, 2021). It provides a rich source of vitamins, minerals, and antioxidants, making it essential in human diets. Global demand for tomato is continuously rising, yet achieving higher yields and better fruit quality remains a challenge due to suboptimal crop management practices. Among various agronomic factors, plant spacing is critical, as it directly influences light interception, nutrient uptake, photosynthetic efficiency, and ultimately yield (Hossain *et al.*, 2019). From an economic perspective, tomato cultivation offers higher profitability per hectare compared to many other vegetables because of its short duration, high yield potential, and suitability for off-season production using improved varieties such as BARI releases. Tomatoes also play a vital role in crop diversification, allowing farmers to generate income during the

winter and, with heat-tolerant varieties, in summer seasons as well (Rahman & Acharjee, 2020). According to recent statistics, tomato is widely cultivated across Bangladesh, particularly in the winter season. Data from the Bangladesh Bureau of Statistics (BBS, 2022) indicate that approximately 27,500 hectares are under tomato cultivation, producing about 389,000 metric tonnes, with an average yield of 14 tha<sup>-1</sup>. However, yields vary considerably depending on variety, season, and management practices. For example, improved varieties such as BARI Tomato -2 and hybrids can yield above 50–65 tha<sup>-1</sup> under favorable conditions. Despite this progress, national yields remain below global averages due to constraints such as improper plant spacing, lack of stress-tolerant varieties, pest and disease pressures, and limited adoption of modern cultivation techniques (Eltez *et al.*, 2002). Expansion of improved varieties and optimized agronomic practices could significantly raise productivity and farmer profitability. One of the main issues with tomato production is inadequate spacing (Aamare & Gebremedhin, 2020).

Proper plant spacing ensures adequate interception of light, efficient utilization of nutrients, and improved aeration, all of which contribute to higher yield and better fruit quality (Eltez *et al.*, 2002; Patil *et al.*, 2018). Inappropriate plant density often results in excessive competition for light, water, and nutrients, leading to reduced growth, smaller fruits, and poor overall yield. Conversely, too wide spacing reduces the number of plants per unit area, which lowers total productivity despite good per-plant performance. Therefore, determining the optimum spacing for tomato cultivation is a critical problem that needs to be addressed for achieving maximum yield and resource-use efficiency.

Several studies across different agro-ecological regions have reported that plant spacing significantly influences tomato growth, canopy structure, fruit size, and marketable yield again, closer spacing increases plant population per hectare but may reduce individual fruit weight due to inter-plant competition. Despite these findings, the optimal spacing often varies depending on location, soil fertility, and climatic conditions. Thus, region-specific spacing recommendations are essential to ensure maximum productivity in different growing environments. According to Abriham & Kefale (2020), Both inter and intra row spacing have negatively impacted tomato production. Wider spacing generally promotes greater vegetative growth and fruit size due to reduced intra specific competition among plants, while narrower spacing may increase total plant population but often results in smaller plants and reduced fruit weight. Further, optimizing plant spacing can enhance resource-use efficiency, improve fruit size and quality, and maximize economic returns. A well-defined spacing system is crucial for sustainable crop production, as it minimizes nutrient losses, improves soil health through better root development, and supports integrated crop management strategies. From several research showed that, wider spacing in different crops increases plant height, number of primary and productive branches, fruit number per plant, and fruit weight, leading to higher biological and economic yields per hectare (Irin *et al.*, 2024; Islam *et al.*, 2011). Conversely, closer spacing can reduce individual plant performance due to inter-plant competition for light, nutrients, and moisture (Irin *et al.*, 2024).

BARI Tomato-2 (also known as Roton), developed by the Bangladesh Agricultural Research Institute (BARI), is one of the most widely cultivated tomato varieties in Bangladesh due to its high yield potential and adaptability across diverse agro-climatic conditions. Under optimal management during the winter season, BARI Tomato-2 produces an average fruit yield, with individual plants yielding around 2.0–2.1 kg of marketable fruit (Rahman *et al.*, 2013). Cultivating BARI Tomato 2 can substantially improve per hectare yields, enhance resilience against climate and soil stress, and contribute positively to farmer incomes. BARI Tomato-2 is well-suited for both smallholder farmers and commercial production due to its uniform fruit size, better shelf life, and higher market acceptability. Its wide adaptability across winter and summer seasons provides flexibility in crop planning and enhances farmer profitability. Although numerous

studies have examined plant spacing in tomato, there is limited experimental evidence in specific regions such as the Rajshahi area under current climatic and soil conditions. Most existing research has focused on generalized recommendations without addressing location-specific variations in plant growth responses. This creates a gap in knowledge, as farmers often rely on traditional practices rather than scientifically validated spacing systems. The novelty of this study lies in its focus on evaluating different spacing regimes under local agro-climatic conditions to establish precise, practical guidelines for improving tomato production. The present study aims to evaluate the effect of different plant spacing treatments on the growth, yield, and yield components of tomato under the agro-climatic conditions of Rajshahi. Specifically, the study seeks to determine the spacing that maximizes both per-plant and per-hectare productivity, thereby providing region-specific recommendations for tomato growers.

## MATERIALS AND METHODS

### About the study area

The experiment was conducted at Rajshahi region during December, 2024 to May, 2025. The location of the site is between 24°36' and 24°37' North latitude and between 88°60' and 88°62' East longitude under the AEZ-26. BARI Tomato-2 were used as experimental materials. Seed was collected from Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. The plot size used was 1.6 m x 5 m (Plot area = 8 m<sup>2</sup>) for the study. The seeds were sown in seedbed on 02 December, 2024. Proper care and management were done for raising seedlings. The seedlings were transplanted at the experiment field on 4 January 2025.

### Experimental design and treatment factors

The experiment was conducted in randomized complete block design (spacing, Varieties) with three replications. Different spacing (Row to row and plant to plant distance was (D<sub>1</sub>=40cm x 45cm; D<sub>2</sub>=50cm x 45cm; (D<sub>3</sub>=60 cm x 45cm) and varieties (BARI Tomato-2) were combined to form three treatments. Each individual plot was 1.6 m x 5 m (Plot area = 8 m<sup>2</sup>).

### Cultivation practices

The land was ploughed followed by laddering. Fertilizer was used as the recommendation of BARI Krishi Projukti Hatboi, 2019. The fertilizer dose was cow dung 10t/ha, urea 177 kgha<sup>1</sup>, triple super phosphate (TSP) 150 kgha<sup>1</sup>, muriate of potash (MoP) 81 kgha<sup>1</sup>, boron 4 kgha<sup>1</sup>, gypsum 88 kgha<sup>1</sup>, zinc sulphate 5 kgha<sup>1</sup>. Equal amount of fertilizer was used in each plot. Urea splits in 10 DAT (Days after Transplanting), 25 DAT and 35 DAT. The MoP was applied one third at basal dose, one third at 25 DAT and one third at 35 DAT. Rest of all fertilizers were given as basal dose during land preparation. Irrigation was given depending on the soil moisture condition and almost every day at vegetative stage.

## Observations

Five plants were carefully chosen from the interior rows, excluding the border row, specifically for assessing plant height, and other parameters. Data were collected on plant height, days to first flowering, number of fruits per cluster, fruits per plant, fruit weight per plant, biological yield, and total yield ( $t\ ha^{-1}$ ). Biological yield was calculated as: Biological yield ( $t\ ha^{-1}$ ) = Fruit yield ( $t\ ha^{-1}$ ) + Plant dry matter ( $t\ ha^{-1}$ ).

## Statistical analysis

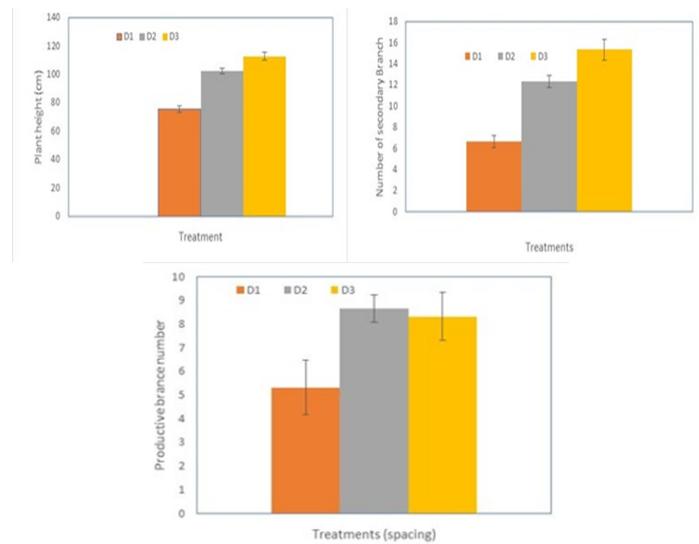
The collected data were analyzed using computer package STATIC-10 package and mean differences were adjudged by using Duncan's Multiple Range Test.

## RESULTS AND DISCUSSION

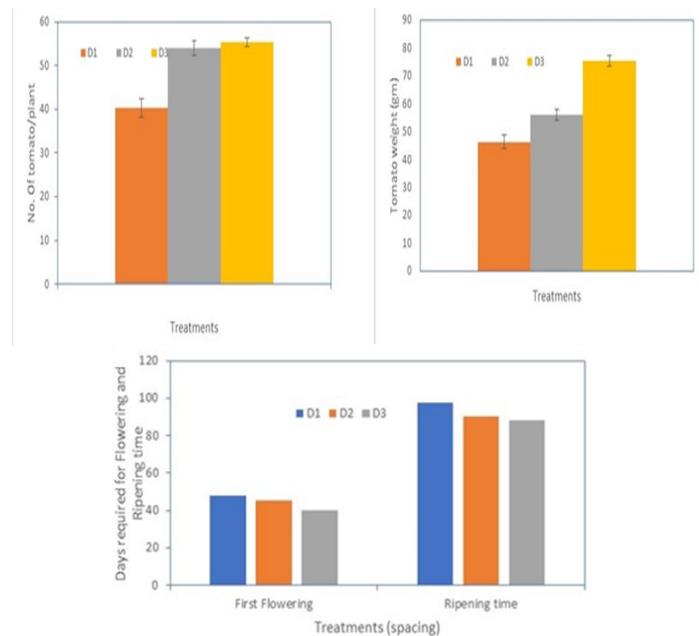
### Growth attributes

**Plant growth and development assessment parameter:** Plant height of tomato plant varies significantly with the variation of spacing (Figure 1). The plant height was varied from 41% to 72% and highest was found from D<sub>3</sub> spacing and it was 72% than D<sub>1</sub>. Whereas D<sub>2</sub> spacing gave the second highest plant height which was at par D<sub>3</sub>. When plant have wider distance between rows, it showed taller plant compared to narrow space. Although different plant needed different spacing but in case of Ratoon variety, it showed sensitive to wider spacing (both inter row and intra row) in the experiment. The current study was agreed with the results of Chernet *et al.* (2017) who reported that the widest inter-row spacing gave the tallest plant compared to close spacing. Number of primary branches also found highest in D<sub>3</sub> spacing and D<sub>1</sub> showed the lowest number (Figure 1). Wider space gave more space plant to produce more branch laterally and it also helped to avail more above and underground nutrients in the experiment. On the other hand, Close spacing tend to impose more competition between plants and reduce the production of lateral branch. Aamare & Gebremedhin (2020) stated that, branches and reproductive structure are the genetic character and it has no effect on spacing. But, in the experiment the test crop showed highest number of primary branches in relation to wider spacing (D<sub>3</sub>). For productive branches, treatments D<sub>2</sub> and D<sub>3</sub> outperformed D<sub>1</sub>, producing 62% and 56% more branches, respectively. This result was supported by Abriham & Kefale (2020) who stated that wider spacing ensures more branches than closed spacing. The wider spacing in the ratoon variety (BARI Tomato-2) allowed greater light interception, enhancing photosynthetic activity and ultimately increasing the number of productive branches (Figure 1).

**Days to first flowering and ripening required for tomato:** Days required to first flowering were identified from 40.00 to 48.00 (Figure 2). Maximum days need for 1<sup>st</sup> flowering was found in closed spacing D<sub>1</sub> (48 DAT) and minimum need required in wide spacing D<sub>3</sub> (40 DAT). Wider spacing of tomato plants can lead to earlier flowering owing to increased access to resources like



**Figure 1.** Effect of spacing on tomato plant height, number of primary and productive branches. (Here, D<sub>1</sub>=40 cm, D<sub>2</sub>=50 cm, D<sub>3</sub>=60 cm).



**Figure 2.** Effect of spacing on tomato plant reproductive parameter. (Here, D<sub>1</sub>=40 cm, D<sub>2</sub>=50 cm, D<sub>3</sub>=60 cm).

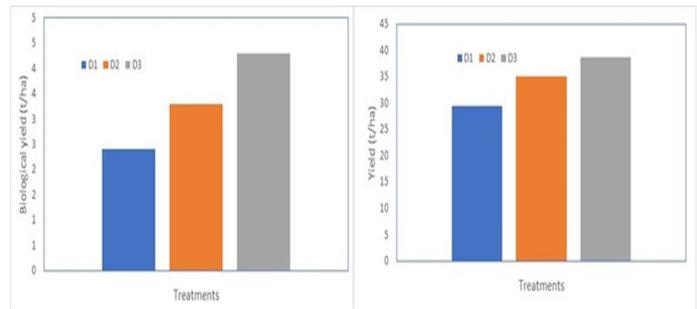
sunlight and soil nutrients. While, plants are spaced further close, they experience high competition for these resources, allowing them to mature and begin flowering later. Furthermore, wider spacing allow plant leaves to get uniform light absorption for photosynthesis and accelerating flowering process. Although tomato is a day neutral plant but, when plants are planted too close together, they compete for essential nutrients and water in the soil which lead to stress, causing the plant to prioritize vegetative growth over flowering. Ripening also enhanced in wider spacing (D<sub>3</sub>) which was at par in D<sub>2</sub> (Figure 2). But D<sub>1</sub> showed in late ripening owing to closed spacing. Wider spacing allows more sunlight to reach the plants, including the lower leaves and developing fruit. This is crucial for photosynthesis, which provides the energy needed for fruit ripening and color development in the present experiment. But Agele *et al.* (1999) reported that the onset of flowering, including the date of 50% flowering, occurred significantly earlier at lower plant densities.

**Number of fruits per plant:** The number of fruits per plant was varied from 40 to 55 (Figure 2). Maximum and minimum number of fruits per plant was recorded with  $D_1$  (40) and highest tomato was found in  $D_2$  (54) and  $D_3$  (55), respectively. In present experiment,  $D_2$  and  $D_3$  gave almost similar results and  $D_1$  gave comparatively smaller size fruits. Wider spacing encourages more fruits per plant owing to more photosynthesis opportunity and more translocation of available nutrients to plant reproductive parts. Whereas, closed spacing imposed more stress to the plants, thus reducing the number of fruits development in the present studies. Nkansah *et al.* (2021) agreed with present studies and stated that the proper space in tomato plant always enhanced the growth and development of the plants, increased light interception through photosynthesis resulting in increased dry matter accumulation and fruit number per plant.

**Fruit weight:** The weight of individual fruit was varied from 46 gm to 75gm (Figure 2). Maximum and minimum weight of individual fruit was observed with  $D_3$  (75gm) and  $D_1$  (40g), respectively. Result showed that Ratoon tomato gave highest weight with wider spacing and lowest fruit weight was observed in closed spacing. Wider spacing in tomato plants generally leads to larger fruit size and consequently higher individual fruit weight. This is because wider spacing reduces inter-plant competition for essential resources like sunlight, water, and nutrients. With less competition, individual plants can allocate more resources to fruit development, resulting in larger fruits. In contrast, closer spacing limited sunlight penetration, which reduced above-ground biomass accumulation and consequently decreased fruit size. This study was agreed with Amundson *et al.* (2012) who stated that wider spacing have positive relation with fruit size.

**Biological yield:** Biological yield in tomato, which includes the total aboveground biomass and fruit yield per unit area, is strongly affected by the density of planting. The biological yield was observed from  $2.2 \text{ tha}^{-1}$  to  $4.3 \text{ tha}^{-1}$  (Figure 3). Maximum and minimum biological yield were recorded with BARI Tomato-2 ( $4.3 \text{ tha}^{-1}$ ) with wider spacing and lower biological yield was recorded in closed spacing ( $D_1$ ). This study was supported by Song *et al.* (2024) and Bertin *et al.* (2003). Intra row competition in closed spacing reduced the accumulation of dry matter through reducing the translocation of sufficient nutrient to the different parts of plants. On the other hand, wider spacing enhancing the proper distribution of nutrients to the plant parts and thus increased the biological yield in the present studies. Although several studies have shown that closer spacing (higher density) increases the biological yield per hectare because of more plants occupying the same land area, even though the number of fruits and fruit weight per individual plant is often reduced.

**Yield ( $\text{tha}^{-1}$ ):** The yield of tomato in the study varied notably across different plant spacings, ranging from 30 to  $38 \text{ t/ha}$  (Figure 3). The highest yield ( $38 \text{ tha}^{-1}$ ) was recorded in  $D_3$ , which corresponded to the widest spacing ( $D_3$ ), whereas the lowest



**Figure 3.** Effect of spacing on tomato plant reproductive parameter. (Here,  $D_1=40 \text{ cm}$ ,  $D_2=50 \text{ cm}$ ,  $D_3=60 \text{ cm}$ ).

yield ( $30 \text{ t/ha}$ ) was observed in  $D_1$ , the closest spacing. This variation reflects the influence of intra-specific competition on plant performance. At wider spacing, plants experienced less competition for light, nutrients, and soil moisture, resulting in improved vegetative growth (greater plant height, more primary branches) and enhanced reproductive development (higher fruit number and weight per plant). These factors cumulatively contributed to greater biological and economic yield. Conversely, closer spacing, while increasing plant population per unit area, restricted individual plant growth due to crowding stress, leading to fewer productive branches, reduced fruit size, and ultimately lower yield per hectare. Similar findings have been reported in earlier studies. Islam *et al.* (2011) found that tomato yield increased with wider spacing due to better resource utilization and reduced disease incidence. Ayarna *et al.* (2021) also highlighting that optimal plant geometry ensures both adequate population density and optimal individual plant performance. Furthermore, dense planting leads to shading effects, suppressing photosynthetic efficiency and fruit development. Thus, the higher yield in  $D_3$  suggests that  $60 \times 45 \text{ cm}$  (or comparable wider spacing) provides a balance between plant population and per-plant productivity, making it the most suitable spacing for achieving maximum tomato yield.

## Conclusion

The study demonstrates that plant spacing has a substantial impact on the growth and yield of tomato (BARI Tomato-2). Wider spacing ( $D_3$ ) resulted in superior vegetative development, higher fruit production per plant, greater biological yield ( $4.3 \text{ t ha}^{-1}$ ), and the highest yield per hectare (26%) compared to closer spacings. These findings indicate that  $60 \times 45 \text{ cm}$  is the most effective spacing for optimizing both plant performance compared to conventional method and overall productivity of tomato (BARI Tomato-2) under the agro-climatic conditions of Rajshahi, Bangladesh.

## DECLARATIONS

**Authors contribution:** Conceptualization, methodology: I.J.I.; Data curation: I.J.I., M.R.J. Writing -original draft preparation: I.J.I.; Writing-review and editing: I.J.I., M.R.J.; Supervision: I.J.I. All authors have read and agreed to the published version of the manuscript.

**Conflicts of interest:** The authors declare no conflict of interest.

**Ethics approval:** This study did not involve any animal or human participant and thus ethical approval was not applicable.

**Consent for publication:** All co-authors gave their consent to publish.

**Supplementary data:** No supplementary data is available for the paper.

**Funding statement:** No external funding is available for this study.

**Additional information:** No additional information is available for this paper.

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