

## Effect of Soil pH on Tomatoes

Siyu Zhang

Lower Canada College Montreal, Quebec Canada H4A 2M5, Canada

### Abstract

Soil pH is an important factor that influences crop planting due to its effects on mineral availability, growth, and reproduction of crops. This study examined the effects of three soil pH levels 5.5 (acidic), 7.1 (neutral), and 8.1 (basic) on the growth, yield, and fruit quality of *Solanum lycopersicum* (Brandywine). An experiment of 15 plants was carried out. Plants were grown outdoors for four months with 5 plants per treatment; vegetative traits, fruit production, and quality parameters were evaluated. Overall, the data suggests that acidic soils had the highest number of fruit per plant ( $13.4 \pm 1.02$ ) and superior quality traits, including mass, °Brix, lycopene, and vitamin C, but also showed an increased incidence of blossom-end rot. Neutral soils demonstrated a more balanced vegetative growth and optimal fruit mineral content, while basic soils resulted in taller plants but significantly reduced yield ( $8.2 \pm 0.75$  fruits per plant) and lower fruit quality. One-way ANOVA confirmed that there are significant differences among treatments ( $p < 0.001$ ). These findings indicate that maintaining soil pH slightly acidic to neutral (6.0-6.8) enhances productivity and quality of fruit in tomato farming.

### Keywords

Soil pH; Tomatoes; Effect; Research.

## 1. INTRODUCTION

Tomatoes are one of the most widely cultivated horticultural crops globally, with an estimated 206.5 million metric tons consumed globally in 2021 [1], [2]. Tomatoes, originally from Central and South America, have become a globally important crop due to their high nutritional value, versatility, and exceptional taste [3], [4]. They are beneficial for health, as they contain major nutrients like vitamin C, potassium, and the antioxidant lycopene [5], [6]. However, tomatoes are highly sensitive to environmental conditions such as light, temperature, and soil conditions [7]. Optimizing tomato growing conditions is therefore an area of focus for agricultural research, particularly in terms of yield enhancement, fruit quality, and environmental tolerance [8], [9]. Since they are sensitive to environmental conditions, tomatoes are ideal models for investigating the influence of soil pH on plant growth and productivity.

Soil pH is a critical factor in plant growth; it determines the availability, abundance, and soil nutrients and soil organisms [10]. Numerous studies have concluded that deviations from a plant's optimal pH range can significantly alter physiological processes, leading to changes in flowering, fruit production, reproduction, and nutrient uptake efficiency [11], [12], [13]. For fruit-bearing crops such as tomatoes, soil pH affects vegetative growth, quality, and flavour of the harvested fruit. Typically, a slightly acidic (pH 5.5 to pH 6.5) soil is ideal for plant growth, as all nutrients, including nitrogen, phosphorus, sulfur, manganese, iron, copper, zinc, boron, and potassium, are available for the plant [14], [15], [16]. Studies show that an increase in pH above 7.5 and a decrease in pH below 5 decrease nutritional availability [17], [18]. Typically, tomatoes should be planted in slightly acidic soil with a pH of 6.2 to 6.8 [19]. However, in many

agricultural settings, soil pH can vary widely due to factors such as irrigation practices, fertilizer use, and soil composition.

In general, soil nutrition has a significant and direct impact on the taste of fruit. Different availability of nutrients affects the accumulation and synthesis of sugar, organic acids, and other compounds that affect the final taste of the fruit. For example, research has shown that the availability of potassium increases the sugar accumulation through carbon flow translocation [20]. Nitrogen influences the content of sugars and organic acids, affecting the taste and flavor of fruits [21]. Deficiencies in these nutrients can result in low sugar and organic content levels, which directly impact the taste of fruits [22]. Nutrient availability and absorption are significantly related to soil pH. Therefore, suboptimal soil pH can disrupt important growth processes, such as metabolic pathways that produce taste compounds, leading to bland, sour, or even poor fruit textures. Understanding the relationship between soil nutrition and pH-mediated availability is therefore important for optimizing fruit quality in tomato cultivation.

Despite growing interest in the effect of soil pH on fruit quality, few studies have researched the direct impact of soil pH on the taste of tomato fruit under real growing conditions. In the first place, there are currently relatively few studies directly on the effect of soil pH on taste. Instead, most studies tend to focus on the effect of soil pH on the nutrition of the final harvest. While previous research has highlighted the role of nutrients in determining tomato sweetness and acidity, the direct relationship between soil pH and fruit taste is relatively understudied. Additionally, many experiments are conducted in controlled solution-based systems, which limits their relevance to actual field conditions. Since soil pH significantly influences the solubility of nutrients and their absorption by roots, it affects key taste qualities. However, there are not enough controlled, long-term studies that measure how specific soil pH levels change these taste qualities throughout the plant's growth.

To address the lack of direct studies on how soil pH affects the taste of tomatoes, this research systematically examines the impact of three soil pH levels—5.5, 7.1, and 8.1—on the development and fruit quality of *Solanum lycopersicum*. These three pHs are chosen to experiment on pHs outside of the zone where tomatoes should typically be grown. This experiment isolates soil pH as the sole independent variable, assessing its direct impact on fruit quality, including yield, taste, physical appearance, and disease presence. Importantly, this research is conducted in an outdoor natural environment to mimic realistic growing scenarios. By integrating both growth-stage observations and final fruit quality, this study aims to provide a clear understanding of the effect of soil pH on fruit quality and taste. The experiment focuses on the later phases of the growth, such as the fruiting stage. The outcomes aim to inform growers about the potential of soil pH management to influence fruit taste, thereby contributing to more precise tomato cultivation practices. Therefore, this study directly addresses a key knowledge gap in the current understanding of soil–plant–flavour interactions in agricultural systems.

## 2. MATERIALS AND METHODS

### 2.1. Experiment Design

A greenhouse experiment was conducted to investigate the impact of pH on the growth of *Solanum lycopersicum*. The experiment includes 3 different soil pH levels, ranging from 5 to 8 (acidic, neutral, and basic). Plant samples are grown from seeds. The seeds were placed in a solution of potassium permanganate until they began to germinate, at which point they were transferred to the soil. A total of 15 plants were planted: 5 plants per pH with 3 different soil pH levels. The experiment was completed in 4 months.

## 2.2. Planting Soil

The soil used for the experiment was Expert Gardener Top Soil, obtained from a commercial garden centre located in Montréal, Canada (45° 30' 31.9968" N, 73° 33' 42.0048" W). This soil had not previously been used for cultivating *Solanum lycopersicum* and was chosen to ensure a consistent and pathogen-free medium across all treatment groups. Prior to use, the soil was passed through a 2 mm sieve to remove debris and achieve uniform texture across replicates.

To characterize the initial soil properties, soil samples were collected to analyze their nutrient content and composition. The initial chemical compositions of the soils are as follows:

0.03% Nitrogen

0.003% Phosphoric Acid ( $P_2O_5$ )

0.003% Soluble Potash ( $K_2O$ )

15.0% Organic Matter

70.0% Moisture (Active ingredients derived from exempt materials)

To manipulate soil pH, two chemical agents were employed:

Acetic acid ( $CH_3COOH$ ) was used to lower the pH (acidify the soil)

Calcium carbonate ( $CaCO_3$ ), finely powdered agricultural lime, was used to raise pH (alkalize the soil)

Soils were divided into three treatment groups, with each batch adjusted to one of the following target pH levels:

Acidic: pH 5.5

Neutral: pH 7.1

Basic: pH 8.1

The pH was adjusted by thoroughly mixing acetic acid or calcium carbonate into water. The acidic/basic solution was then mixed with the soil before transplanting. Adjustment quantities were determined through preliminary titration tests, using incremental addition of  $CH_3COOH$  and  $CaCO_3$  to 250 g samples of the experimental soil until desired pH levels were stabilized. Final pH values were confirmed using a calibrated digital soil pH meter, utilizing a 1:2 soil-to-distilled water suspension by mass, and measured under laboratory conditions at room temperature ( $22 \pm 1^\circ C$ ).

Following transplantation, the soils were watered daily with pH-matched water to maintain chemical consistency. Water used for irrigation was pretreated to match the soil group pH using the same reagents (acetic acid or calcium carbonate). The volume of water applied was standardized to 250 mL per pot every 7 days at the beginning of the experiments. Once the plants are grown, water is applied every 2 days.

Soil pH was monitored daily, using the same 1:2 soil to distilled water ratio method, and values were recorded. If the soil pH deviated by more than  $\pm 0.2$  pH units from the target value, corrective adjustments were made by applying a diluted solution of the respective acid or base. Over the course of the experiments, all soil pH values were kept within  $\pm 0.2$  pH units of the target values.

All containers used for planting were thoroughly cleaned and drained to prevent cross-contamination. Pots were kept in isolated plots to avoid runoff between treatments.

## 2.3. Planting Material

*Solanum lycopersicum* was chosen as an experimental plant due to its agricultural relevance. The experiment began with the stage of seeds. Seeds were obtained from existing *Solanum lycopersicum* and are all from the same cultivar—Brandywine.

Before planting, the seeds were surface sterilized using a 0.3% (m/v) potassium permanganate ( $\text{KMnO}_4$ ) solution for a duration of 40 minutes to reduce the risk of fungal or bacterial contamination. After sterilization, the seeds were rinsed 3 times with distilled water to remove any  $\text{KMnO}_4$  remaining. The seeds were then placed in moist filter paper for germination. Germination was done at room temperature and moisture (approximately 23°C and 40%). The filter papers were kept moist with distilled water and checked daily.

Once radicle emergence reached a minimum length of 1 cm (typically 5–7 days post-treatment), the germinated seedlings were transferred into individual experimental containers. Each seedling was planted at a uniform depth of 3.0 cm in pre-treated soil according to its assigned pH group (5.5, 7.1, or 8.1). A total of 15 seedlings were transplanted, with five replicates per pH treatment.

In order to minimize environmental variability, all seedlings were transplanted at the same time, and care was taken to ensure that soil compaction and planting depth were as consistent as possible across all pots. No growth stimulants or root hormones were applied during the transplanting process. Seedlings were labelled and tracked individually throughout the experiment.

After the transplant process, 15g of actisol chicken manure was applied weekly with the following chemical properties:

5% Nitrogen

3% Phosphoric Acid ( $\text{P}_2\text{O}_5$ )

2% Soluble Potash ( $\text{K}_2\text{O}$ )

7% Calcium (Ca)

0.5% Magnesium (Mg)

0.1 % Iron (Fe)

71.0% Organic Matter

10.0% Maximum Moisture

## 2.4. Environmental Control

All 15 pots were grown outdoors under natural environmental conditions typical of the Montréal region during the summer months. The average daily temperature ranged from 25°C to 32°C, with nighttime lows around 15°C. The relative humidity varied between 50% and 95%, depending on weather conditions. The photo period was relatively consistent over the course of the experiment, approximately 12 hours of daylight. Although grown outdoors, all pots were sheltered from direct precipitation using transparent plastic covers to eliminate rain as an external factor of pH variation while still allowing full light penetration. Additionally, pot placement was arranged to ensure even light exposure across all samples, and containers were rotated weekly to minimize microenvironmental variation.

## 3. RESULTS

### 3.1. Vegetable Growth

Plants in all soil conditions exhibited a similar growth pattern during the early stages of the experiment; however, the duration of the growth period varied significantly across the three soil conditions. Tomatoes in an acidic environment showed the shortest period of growth ( $32.6 \pm 1.7$  days); plants in neutral soil conditions showed a moderate growth period ( $38 \pm 1.22$  days), and plants in basic soil conditions showed the longest growth period ( $44.4 \pm 1.02$  days). The plants' final height varied significantly, with acidic being the shortest, followed by neutral and basic (Table 1).

At the same time, the number of flowers follows a similar trend (Table 1), with acidic soil producing the most flowers, followed by neutral soil, and lastly basic soil conditions. Tomatoes planted in acidic soil conditions were the first to flower, followed by plants in neutral conditions, and lastly, plants in basic conditions (Table 1).

Specific details about the vegetative growth of each plant can be found in Table 1.

**Table 1.** Growth and Reproductive Traits of Tomato Plants under Different Soil pH Treatments.

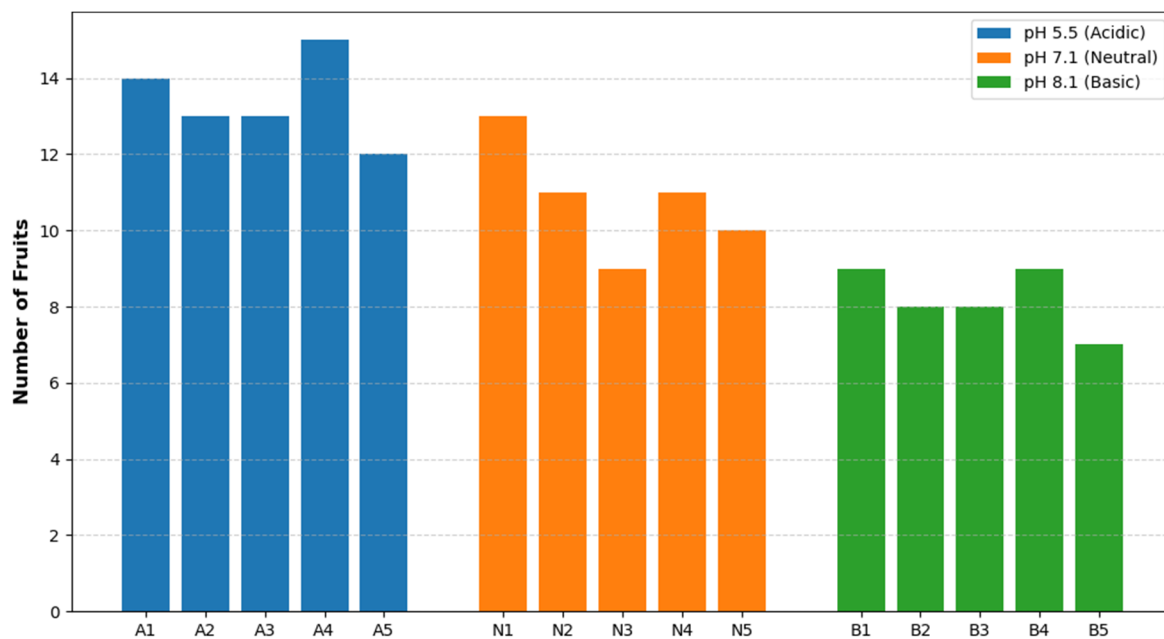
| Plant | pH  | Plant height (cm) $\pm$ 0.5cm | # leaves | # flowers | Time to first flower (days after translocation) | Stem diameter (cm) $\pm$ 0.1cm |
|-------|-----|-------------------------------|----------|-----------|-------------------------------------------------|--------------------------------|
| A1    | 5.5 | 53.7                          | 14       | 7         | 32                                              | 2.2                            |
| A2    | 5.5 | 58.3                          | 15       | 8         | 35                                              | 2.5                            |
| A3    | 5.5 | 60.2                          | 16       | 9         | 34                                              | 2.5                            |
| A4    | 5.5 | 59.3                          | 16       | 10        | 30                                              | 2.4                            |
| A5    | 5.5 | 64.7                          | 17       | 8         | 32                                              | 2.6                            |
| N1    | 7.1 | 89.3                          | 21       | 5         | 38                                              | 2.3                            |
| N2    | 7.1 | 96.2                          | 24       | 7         | 39                                              | 2.6                            |
| N3    | 7.1 | 83.2                          | 19       | 4         | 39                                              | 2.4                            |
| N4    | 7.1 | 97.7                          | 24       | 7         | 36                                              | 2.7                            |
| N5    | 7.1 | 93.2                          | 22       | 6         | 40                                              | 2.5                            |
| B1    | 8.1 | 104.5                         | 26       | 6         | 43                                              | 2.3                            |
| B2    | 8.1 | 110.3                         | 27       | 3         | 45                                              | 2.4                            |
| B3    | 8.1 | 112.5                         | 27       | 4         | 46                                              | 2.6                            |
| B4    | 8.1 | 106.8                         | 26       | 5         | 44                                              | 2.4                            |
| B5    | 8.1 | 115.7                         | 29       | 4         | 44                                              | 2.7                            |

### 3.2. Reproductive Development

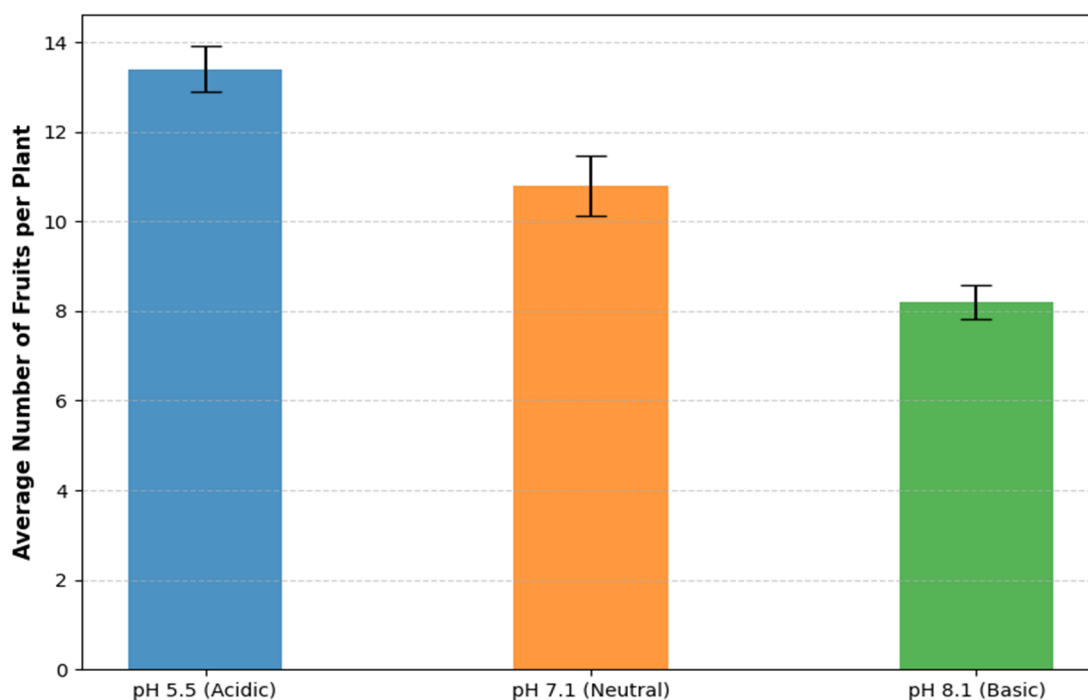
Plants grown in acidic soil conditions produced the highest number of fruits ( $13.4 \pm 1.02$  fruits), followed by neutral ( $10.8 \pm 1.33$  fruits), while basic soil conditions yielded the fewest fruits ( $8.2 \pm 0.75$  fruits). One-way ANOVA test for the number of fruits across the three soil pH levels showed a significant difference ( $p < 0.001$ ), indicating that soil pH has a strong effect on fruit production in tomatoes. Specifically, plants grown in acidic soils produced significantly more fruits compared to those in neutral and basic soils, while basic soils consistently yielded the fewest fruits.

A notable discovery is that tomatoes grown in acidic soil conditions are more likely to develop blossom-end disease. During fruit production, many tomatoes with blossom-end disease were discovered, specifically in tomatoes planted in acidic conditions; a total of 8 tomato fruits with blossom-end disease were discovered out of 67 fruits. Plants in neutral or basic conditions do not have any signs of this disease.

Specific details about the number of fruits of each plant can be found in Figures 1 and 2.



**Figure 1.** Number of Fruit of Tomatoes in Different Soil pH



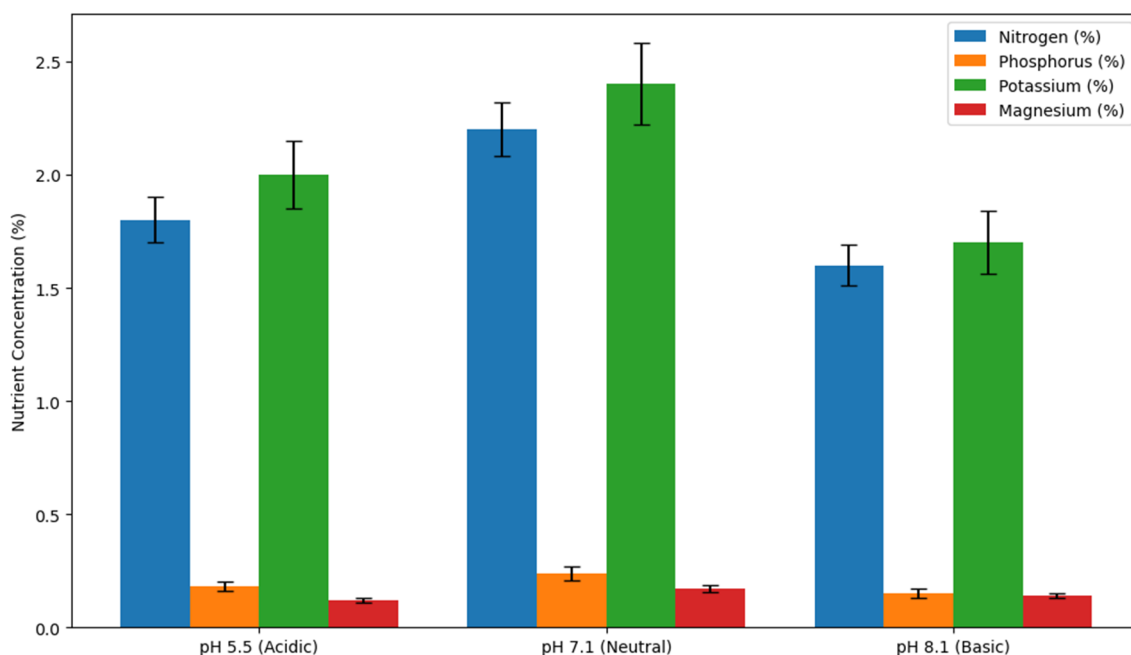
**Figure 2.** Average Number of Fruit of Tomatoes in Different Soil pH

### 3.3. Fruit Quality

Tomatoes planted in acidic soil yielded fruits with the highest average masses ( $305 \pm 4.7\text{g}$ ), followed by neutral soil conditions ( $297 \pm 3.8\text{g}$ ) and basic soil conditions ( $284 \pm 6.3\text{g}$ ). Details about fruit quality are presented in Table 2; Fruit mineral contents are presented in Figure 3. One-way ANOVA single factor shows a significant variation between soil pH and the different mineral content of tomato fruits, as well as the different traits of fruit quality ( $P$  value  $< 0.0001$ ).

**Table 2.** Average Fruit Quality of Tomatoes in Different Soil pH

| Traits | Fruit diameter (cm) | Fruit mass (g) | °Brix         | Lycopene (mg/kg) | Vitamin C (mg/100g) |
|--------|---------------------|----------------|---------------|------------------|---------------------|
| pH 5.5 | $10.1 \pm 0.2$      | $305 \pm 4.7$  | $6.2 \pm 0.1$ | $91 \pm 2$       | $24.4 \pm 0.4$      |
| pH 7.1 | $9.9 \pm 0.2$       | $297 \pm 3.8$  | $5.9 \pm 0.1$ | $86 \pm 2$       | $22.1 \pm 0.4$      |
| pH 8.1 | $9.3 \pm 0.3$       | $284 \pm 6.3$  | $5.3 \pm 0.1$ | $78 \pm 2$       | $20.9 \pm 0.4$      |



**Figure 3.** Average Fruit Mineral Composition of Tomatoes in Different Soil pH

## 4. DISCUSSION

The results of this study demonstrate that soil pH significantly affects the growth, reproductive development, and fruit quality of tomatoes. All plants have a similar growth trend during the early stages of growth. However, there are clear differences in vegetative traits, yield, and fruit quality.

### 4.1. Vegetative Growth and Reproductive Development

Despite tomatoes planted in acidic soil exhibiting the shortest growth period and final plant height, they produced the most flowers and fruits. These results therefore suggest that an acidic environment accelerates developmental transitions such as flowering and reproduction. The short final height can thus be explained by the quick transitioning into the next phase. In contrast, tomatoes planted in basic soil conditions exhibit the longest growth period, resulting

in the highest plant final height at the cost of fewer flowers and fruits. Neutral soil conditions showed an intermediate growth pattern, with moderate height, number of flowers, as well as yield. This aligns with previous reports that optimal tomato productivity occurs in slightly acidic to near-neutral conditions [23].

A noteworthy finding is the disease of blossom-end rot occurring solely in tomatoes planted in acidic soil conditions. Out of all 67 fruits produced by acidic tomatoes, 8 tomatoes were observed having blossom-end rot disease. Blossom-end rot is associated with calcium deficiencies in the fruit tissue. Calcium deficiency is common in acidic soil because the acidic condition reduces calcium availability and transport. This indicates that while acidic soils may increase yield, they raise the risk of diseases that compromise fruit marketability and decrease overall yield.

#### 4.2. Fruit Quality

Fruit quality, both biochemical and physical, is also significantly affected by soil pH. Fruits produced in acidic soil demonstrated a larger diameter and mass compared with neutral or basic soil conditions. This is consistent with previous research stating that soil acidity increases carbon assimilation and fruit sink strength [24], [25]. However, tomatoes planted in neutral soil conditions exhibit a very similar pattern, with slightly lower quality traits compared with acidic soil conditions. Tomatoes planted in basic soil conditions demonstrate a large difference in fruit quality.

Moreover, °Brix values and lycopene concentration were also the highest in tomatoes planted in acidic conditions, suggesting that acidity enhances sugar synthesis. These traits are directly associated with the taste of fruits, such as sweetness, as well as color perception. Tomatoes planted in neutral soil conditions still exhibit a relatively high level of °Brix, lycopene, and Vitamin C content. However, basic soil conditions resulted in fruits with significantly lower °Brix, lycopene, and Vitamin C content.

#### 4.3. Nutrient Composition

The mineral content of fruits also varied significantly according to pH, as shown by the ANOVA single-factor result. This time, nitrogen, phosphorus, potassium, and magnesium concentrations were highest in neutral soil conditions, suggesting that a soil condition closer to neutral is optimal for nutrient intake balance. Soil conditions, either too acidic or too basic, lead to inefficiency in nutrient intake. This corresponds with previous research stating that extreme soil conditions limit the availability of essential nutrients to plants and hinder beneficial soil microbial activity [26].

#### 4.4. Implications for Cultivation

Overall, the findings highlight the tradeoffs of growing tomatoes in acidic, neutral, or basic soil conditions. Acidic soils increased yield, fruit sweetness, and lycopene levels in tomatoes. However, it also comes with the disadvantage of an increased likelihood of experiencing blossom end rot. Neutral soils seem to have well-balanced vegetative growth, nutrient composition, and consistent fruit quality. Basic soil conditions resulted in a longer growth period, but lower yield as well as fruit quality.

These findings help tomato growers understand the importance of maintaining soil pH in the slightly acidic to neutral range (6.0-6.8), to keep high yield, but also fruit quality. Soil with more acidity may need additional calcium to help in controlling the likelihood of blossom end rot, whereas alkaline soils would require amendments (i.e., acidifying amendments like sulfur or incorporating organic matter) to decrease soil pH, or to mitigate the likelihood of blossom end rot, and achieve an increase in the normal tomato nutrient availability.

## 5. CONCLUSION

### 5.1. Limitations and Future Direction

While this experiment brought many valuable insights, several limitations must be acknowledged. First, this experiment was conducted on a single species of *Solanum lycopersicum*, limiting the generalizability across other tomato varieties. Therefore, future research could focus on implementing other species of commonly cultivated tomatoes to research more generally about the effect of soil pH on tomatoes.

Moreover, the dependent variable, soil pH, was limited; only three different pHs were tested (5.5, 7.1, 8.1). Most importantly, the pHs were separated by a significant amount, especially between acidic and neutral. The lack of treatment of tomatoes in a soil pH of 6.2 to 6.8 leaves gaps for interpretation, as 6.2 to 6.8 is generally considered the optimal pH for tomato growth. Therefore, the lack of a more specific pH difference may overlook the range of pH most relevant for growers. Future work could thus research the effect of soil pH using pHs with smaller differences to have more accurate results; at the same time, a soil pH between 6.2 and 6.8 should be considered.

Lastly, this experiment was performed in containers, rather than in the field. This limitation may restrict the accuracy of the results to more practical cultivating conditions. Container systems may limit root growth, restrict the movement of natural water and nutrients, and oversimplify soil microbial dynamics compared to field soils. As such, these limitations may amplify or diminish the impact of soil pH on nutrient availability and plant growth. Consequently, the results may not fully reflect how tomato plants would respond to soil pH variation under field conditions, where other factors such as micro-organism activities and buffering effect may also play a role in the growth and reproduction of tomatoes. Future studies should therefore include field trials to confirm and extend the findings presented in this experiment, as field trials provide a more accurate reflection of practical cultivation conditions.

### 5.2. Conclusion

This study demonstrates the effect of soil pH on the growth, yield, and fruit quality of *Solanum lycopersicum*. By experimentally comparing the three soil conditions (pH 5.5, pH 7.1, and pH 8.1), a clear difference between the growth, reproduction, and fruit quality of *Solanum lycopersicum* is discovered.

Tomatoes grown in acidic soil conditions showed the highest number of flowers, yield, along with the highest °Brix, lycopene, and vitamin C concentrations, suggesting an advantage in terms of flavor and fruit coloration. However, disadvantages exist, such as the increased incidence of blossom-end rot, highlighting the trade-off between yield and fruit marketability. Neutral soil conditions (pH 7.1) supported balanced vegetative growth and a relatively optimal yield. At the same time, neutral soil conditions resulted in the most optimal fruit mineral content, shown by the highest mineral concentration out of all three soil conditions.

Basic soil conditions (pH 8.1) resulted in taller plant growth and longer growth periods but reduced both yield and fruit quality traits. These results highlight the importance of maintaining soil pH in the slightly acidic to neutral range (6.0–6.8) for optimizing both productivity and fruit quality in tomato cultivation.

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