International Journal of
Agro Chemistry

ISSN: 2456-7000
Volume 11, Issue 2, 2025
July–December
DOI (Journal): 10.37628/IJA

https://journalspub.com/journal/ija/

Research IJA

Effect of Soil pH on the Germination and Growth of *Triticum aestivum* (Wheat) and *Zea mays* (Maize)

Ashwani Sharma[1], Abha Vasal[2], Richa Arora[3,*]

Abstract

Because of its effects on nutrient availability, microbial activity, and the solubility of hazardous elements, all of which can have a substantial impact on crop productivity, soil pH is a crucial factor determining plant growth and development. Understanding how different pH levels affect the vegetative growth of crops is crucial for optimizing agricultural practices. This study examines the impact of soil pH – acidic, neutral, and alkaline – on the vegetative growth of wheat (Triticum aestivum var. PBW-502) and maize (Zea mays var. PMH-12) from the seedling stage to maturity. The research was conducted under both pot and field conditions to gain a comprehensive understanding of the relationship between soil pH and crop development. The investigation, carried out during the Rabi seasons of 2022–2024, included preliminary germination tests in petri dishes across a pH range of 4 to 10, followed by plant growth in soils with pH values of 4 (acidic), 6 (neutral), and 10 (alkaline). Acidic soil was sourced from a village in Haryana (a state of India) known for its acidic soil history, while alkaline soil was created by treating garden soil with calcium hydroxide. The results showed that both wheat and maize performed best in neutral pH conditions, although maize demonstrated better tolerance to alkaline soil compared to wheat.

Keywords: Wheat, maize, acidic soil, alkaline soil, problem soil, crop yield

INTRODUCTION

Agriculture has always been driven by the available technology and the need to meet humanity's food requirements. In recent decades, however, a third factor has emerged in this equation: the environment. Historically, agricultural development has often led to environmental pollution and the unchecked exploitation of natural resources. To address these issues, new global regulations are being introduced to protect the environment and foster a sustainable economy. A prime example is the European Union (EU) Green Deal, which aims to make Europe the first climate-neutral continent [1]. A key component of this initiative is sustainable agriculture, which emphasizes resource conservation, recycling, ecological practices, and the latest technological innovations. Additionally, it is crucial to shift our perception of soil, recognizing its central role in agricultural development and food security. As a non-renewable natural resource, healthy soil is essential for sustainable agriculture [1].

Soil pH is a critical chemical factor influencing soil health, soil nutrient availability, nutrient uptake by plants, and plant growth [1–3]. Fertilizers, whether synthetic or organic, will not be effective if soil pH is not properly managed. Soil pH also impacts nutrient availability, soil

***Author for Correspondence**
Richa Arora
E-mail: richaarora@shivaji.du.ac.in

[1]Assistant Professor, Department of Environmental Studies, Shivaji College, University of Delhi, Raja Garden, New Delhi, Delhi, India.
[2]Assistant Professor, Department of Computer Science, Shivaji College, University of Delhi, Raja Garden, New Delhi, Delhi, India.
[3]Assistant Professor, Department of Chemistry, Shivaji College, University of Delhi, Raja Garden, New Delhi, Delhi, India.

Received Date: April 30, 2025
Received Date: May 11, 2025
Published Date: June 18, 2025

Citation: Ashwani Sharma, Abha Vasal, Richa Arora. Effect of Soil Ph on the Germination and Growth of *Triticum aestivum* (Wheat) and *Zea mays* (Maize). International Journal of Agrochemistry. 2025; 11(2): 1–8p.

biology, and pesticide efficacy. However, due to the variation in soil types and crop needs, there is no single ideal pH. While most crops thrive in a pH range of 6.0 to 6.5, producers can optimize yields by better understanding soil characteristics and how crops respond [4]. The pH scale (ranging from 0 to 14) measures hydrogen ion concentration, which determines acidity. A pH of 7 is neutral, while lower values are acidic and higher values are alkaline. Although a neutral pH of 7 might seem ideal, plant toxicity from hydrogen ions does not occur until the pH drops below 4.5. Toxicity in acidic soils is more often caused by elements like aluminum, iron, and manganese. With increasing variety and hybridization, it becomes more difficult to predict variability within crops. The uptake of nitrate by plants is most efficient at lower pH levels, while ammonium is absorbed better at neutral pH. Phosphorus availability is optimal at pH 6.5. Below this, phosphorus becomes less available as it binds with aluminum/iron minerals or adsorbs to soil oxides and clay. Above pH 6.5, Phosphorous combines calcium, forming solid minerals like Ca-phosphate fertilizers. Potassium, calcium, and magnesium become less available in acidic soils because they are leached out, rather than due to solubility issues [4–5].

In alkaline soils, calcium is often present in the form of calcium carbonate, but micronutrients generally decrease in availability as pH increases [4]. Elements, like zinc, copper, and manganese, decrease dramatically in concentration with every one-unit increase in pH. These nutrients bind to soil surfaces, making them unavailable to plants. Severe deficiencies of these micronutrients can cause noticeable symptoms in crops. If micronutrient deficiencies are detected in acidic soils, it is likely due to lower concentrations and the leached nature of the soil [4].

The pH buffering capacity of soil can vary significantly depending on its composition and the distribution of substances, like organic matter or calcium carbonate, which play key roles in stabilizing pH levels. Although few studies have assessed the effects of pH in soil-grown plants, it is understood that pH affects nutrient availability [6]. When planning new gardens or landscapes, checking soil pH is essential, as different plants have different pH requirements for optimal growth. For most crops, a pH between 6.0 and 7.5 is ideal, as it ensures that most nutrients are readily available [5].

Wheat and maize are two of the most widely cultivated crops and, hence, fulfill the food requirements of the world's growing population. Maize is the world's leading cereal in terms of production, and wheat ranks as the third most produced cereal globally, after rice [7]. Despite the well-established significance of both crops in fulfilling worldwide food demand, they face numerous challenges in terms of production. In 2023, a group of scientists sought to determine the effect of using acidified biochar on the growth of maize. Their findings suggest that the yield of maize could be increased by reducing the soil pH of alkaline soils through the application of biochar. This is because, in highly alkaline soils, nutrient availability is limited [8]. A detailed analysis of the effect of acidic soil pH on the growth of maize has been reported [9], which suggests that acidic soil could lead to a yield loss of maize production by up to 69%. Wheat production is also severely affected by acidic pH, a fact proven by studies conducted in Ethiopia, one of the largest wheat-producing countries in Africa [10].

This paper focuses on the impact of soil pH on the growth and yield of wheat and maize under both acidic and alkaline soil conditions. By reviewing recent studies and employing field and experimental research, this paper aims to assess the influence of various pH levels on plant growth. The present research seeks to offer insights into improving crop productivity in suboptimal soil conditions and the sustainable agricultural practices required to support the ever-growing population. The current investigation will provide a deeper understanding of how soil pH affects the growth and health of wheat and maize and suggest viable solutions for improving crop yields in affected regions, particularly in India.

MATERIALS AND METHODS

Problem soil samples were collected from a specified location in Garhwal village, Sonipat district, Haryana state of India. The site was intentionally selected for its history of reported acidic locations scattered in the region. The pH level of each soil sample was measured with a portable soil pH and EC meter. The soil sample procured was prepared following standard procedures before being used for the experiments. Stones, dry leaves, or any other particulate matter were removed manually. The soil was then allowed to pass through sieves to collect fine soil particles. The resulting soil sample was used as the problem soil. Acidic solutions were prepared using aluminum sulfate, and alkaline solutions were prepared using calcium carbonate. The pH of the prepared solutions was determined using a digital pH meter.

The first stage of the study, which started in December 2019, involved planting wheat and maize seeds in experimental pots. The soil sample was collected from the garden of Shivaji College, University of Delhi, Delhi, India and the same treatment was applied as was done for the problem soil. A total of four solutions were prepared with pH values of 4.295, 8.425, 10.030, and 12.424, which were used to prepare experimental soil samples. Duplicate pots of each soil type were prepared, and each pot was planted with an equal number of wheat seeds. Similar duplicate pots were prepared for sowing maize seeds. The planting instructions provided on the seed packet were followed. The plots were watered regularly, including at critical stages, for both plant types. NPK fertilizer and compost were applied as per standard methods.

The second stage of the study was initiated in December 2020, which involved the use of crates sized 14 inches x 21 inches x 11 inches. The planting process was like that of the first stage. Watering and use of fertilizers were the same as in the first stage.

The quality of soil samples with pH values of 4.000 (problem soil), 6.000 (control soil), and 10.030 (experimental soil) were sent to the Central Laboratory for Soil and Plant Analysis, Division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi, for testing.

The third and final stage spanned two seasons: December 2022–April 2023 and December 2023–April 2024. In the last stage, only three soil samples were used, and their testing was done. Again, crates were used, which could emulate small experimental fields. Growth, in terms of shoot length of wheat and maize plants, was monitored and recorded regularly throughout all stages of the study.

RESULTS

The growth and yield of plants are significantly influenced by soil pH, as it affects various physiological, chemical, and biological processes occurring in the soil. *Triticum aestivum* (wheat) and *Zea mays*(maize) are the two major cereal crops grown worldwide, and their growth and productivity are significantly influenced by soil pH. In this paper, we discuss the effects of soil pH on the growth of *T. aestivum* and *Z. mays* and provide insights into the optimal soil pH range for their growth.

The experiment was conducted in three stages. The first stage involved planting wheat and maize seeds in small pots. In the second stage, seedlings were grown and monitored in small crates with dimensions of 14 inches x 21 inches x 11 inches. The growth of both types of seeds was monitored, and the length of seedlings of both wheat and maize was noted across two seasons: December 2019 to April 2020 and December 2020 to April 2021. For these two stages, the problem soil was collected from the Sonipat area of Haryana (as mentioned in the previous section), and its pH was found to be 4.0 using a handheld soil pH meter. A control soil sample was collected from the gardens of Shivaji College. The control soil was treated with pH solutions of 4.295, 8.425, 10.030, and 12.424 to prepare different experimental soil samples. Seeds of wheat and maize were planted in duplicate pots of each experimental sample, as well as the problem and control soils. The same procedure was followed for the second stage, with the only difference being that, in this stage, crates of size 14 inches x 21 inches x 11 inches were used instead of earthen pots. In both stages, the maximum shoot length was found for the highly basic experimental soil sample with a pH of 12.424, which produced 13 wheat pods. No growth was observed for either of the crops in the problem soil. To further expand the research work, the control soil, problem soil, and experimental soils with pH values of 4.000 (Soil-2), 6.000 (Soil-1), and 10.030 (Soil-3) were examined for their exact pH, salinity, and nutrient contents. The results are given in Table 1.

Table 1. Soil test report of various soil samples by Central Laboratory for Soil and Plant Analysis, division of Soil Science and Agricultural Chemistry, ICAR-Indian Agricultural Research Institute, New Delhi.

S. N.	Soil Sample	pH	EC (dS/m)
1.	Soil 1	7.48	0.32
2.	Soil 2	8.62	38.0
3.	Soil 3	8.28	0.14

Note: Soil 1 represents control soil, Soil 2 represents problem soil, and Soil 3 represents alkaline soil. EC = electrical conductivity.

The results obtained were contradictory to our measurements. The pH of the control soil was slightly higher than what we had determined (6.000). The pH of the problem soil was found to be alkaline rather than acidic, and the pH of the experimental soil was found to be lower than what we measured. This could be attributed to certain key factors that we might have overlooked while performing our studies. The mismatch in the pH of the problem soil could be due to an inaccurate reading of the handheld soil pH meter. The problem soil was found to be alkaline as well as highly saline judging by its quite high electrical conductivity (EC) value of 38.0 dS/m (Table 1). Alterations in soil quality leads to changes in a plant's biochemical, physiological, and molecular characteristics, which can disrupt its metabolism and nutrition. Soil salinity hampers root growth and the development of aboveground parts, causing symptoms, such as leaf browning or burning, reduced flowering, diminished vigor, dehydration of plant cells, and, in some cases, the death of species less tolerant to salt stress [11]. This presents a significant challenge to achieving the required agricultural productivity, as salinity negatively impacts crop yields. Crops, like maize and wheat, are particularly sensitive to salinity. Depending on the level of soil salinity, the yields of maize and wheat can drop by as much as 50%. However, some crops, such as barley and cotton, are more resistant to salinity [12–13]. It is important to note that salt sensitivity varies throughout the plant's life cycle, being most vulnerable during the seeding and reproductive stages [1].

The lower pH value of the experimental soil could be attributed to the fact that soil resists changes in its pH, so the soil was not as alkaline as initially measured. Regular monitoring of pH and consistent watering of the soil with the prepared pH solution were not performed. The slightly higher pH value of the control soil could be attributed to the lack of regular monitoring of its pH. Although the results obtained in the first two stages were not fruitful, they provided us with the right direction for further studies, especially in terms of the factors to consider when performing additional experiments. Also, it became clear that alkaline soil would yield better results, but saline soil would not.

The third and final stage was conducted over two seasons: December 2022 to April 2023 and December 2023 to April 2024. The studies were performed in crates measuring 14 inches x 21 inches x 11 inches, to emulate small fields. This time, the problem soil was not used. The control soil (pH 6.0) was used, and solutions of pH 4.0 and 10.0 were used to prepare two experimental soil samples. Each of these was planted with an equal number of wheat and maize seeds in duplicates. NPK fertilizer was also used, the soil was watered regularly with the respective pH solutions, and the pH of the soil was monitored regularly. The shoot length of wheat and maize was measured regularly for all soil samples, and the results of both seasons are presented in Tables 2 and 3.

Table 2. Length of various seedlings of wheat and maize grown under different conditions (December 2022 to April 2023).

S. N.	pH of Soil	Seed Grown	Average Length of Seedlings (in cm)		
			December 2022	January–February 2023	March–April 2023
1	4.000	Wheat (Ta)	–	–	–
		Maize (Zm)	–	–	Few saplings
2	6.000	Wheat (Ta)	11.0	19.5	26.0
		Maize (Zm)	7.7	19.9	More than 30
3	10.030	Wheat (Ta)	12.1	18.2	22.0
		Maize (Zm)	7.7	20.3	More than 30

Table 3. Length of various seedlings of wheat and maize grown under different conditions (December 2023 to April 2024).

S. N.	pH of soil	Seed Grown	Average Length of Seedlings (in cm)		
			December 2023	January–February 2024	March–April 2024
1	4.090	Wheat (Ta)	–	–	–
		Maize (Zm)	–	–	Few saplings
2	6.000	Wheat (Ta)	14.1	25.7	More than 30
		Maize (Zm)	18.4	28.3	More than 30
3	10.060	Wheat (Ta)	11.0	23.7	29.4
		Maize (Zm)	19.7	More than 30	More than 30

DISCUSSION

No growth of wheat and negligible growth of maize in acidic soil were observed in both types of experiments (Tables 2 and 3). In neutral and slightly alkaline soils, significant growth of both wheat and maize was observed (Tables 2 and 3). In case of wheat, seeds were obtained in wheat pods for the soil having neutral and alkaline pH. This could be attributed to soil pH and nutrient availability, which significantly influence the availability of essential nutrients to plants.

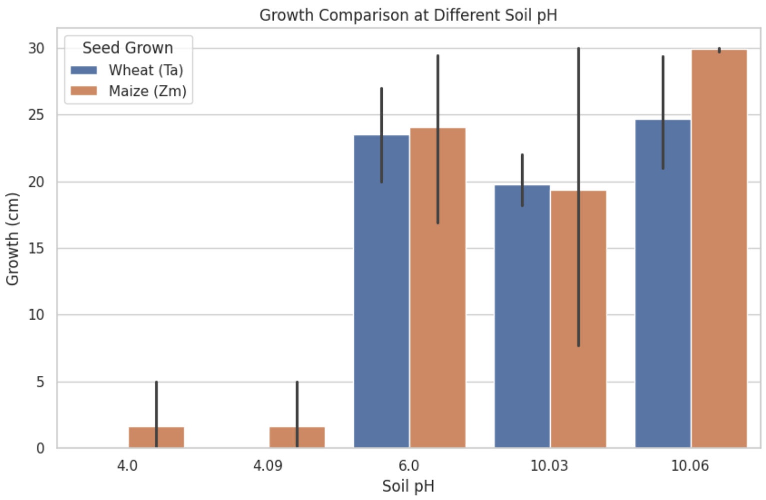

Figure 1. Growth of wheat and maize plants at different soil pH.

The shoot length growth data was analyzed using Python for better understanding. Figure 1 shows that neutral soil pH (~6.0) supports the highest seedling growth, while extreme acidic (4.0) and alkaline (10.0) conditions lead to reduced growth. Maize consistently grows better than wheat across all pH levels, indicating its higher adaptability. This suggests that maintaining soil pH near neutral levels can significantly enhance plant growth and agricultural productivity.

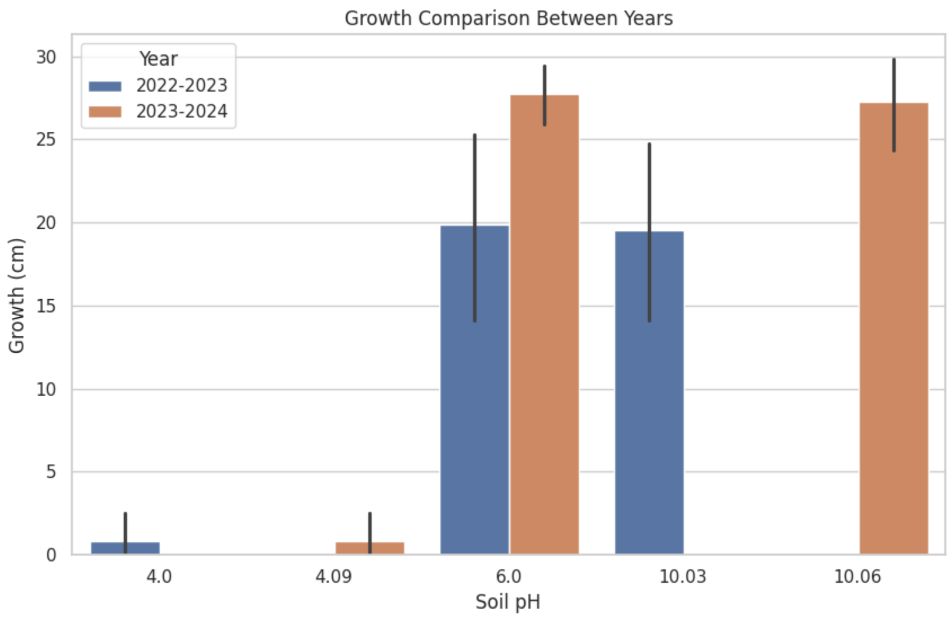

Figure 2. Yearly comparison of growth at different soil pH levels.

The grouped bar chart in Figure 2 shows that seedling growth in 2023–2024 is consistently higher than in 2022–2023 across all soil pH levels, indicating improved environmental conditions or farming techniques. Growth is highest at neutral pH (~6.0) in both years, reinforcing the importance of maintaining optimal soil pH for maximum yield. The increase in growth from the previous year suggests advancements in soil management, irrigation, or climatic factors that favor better crop development.

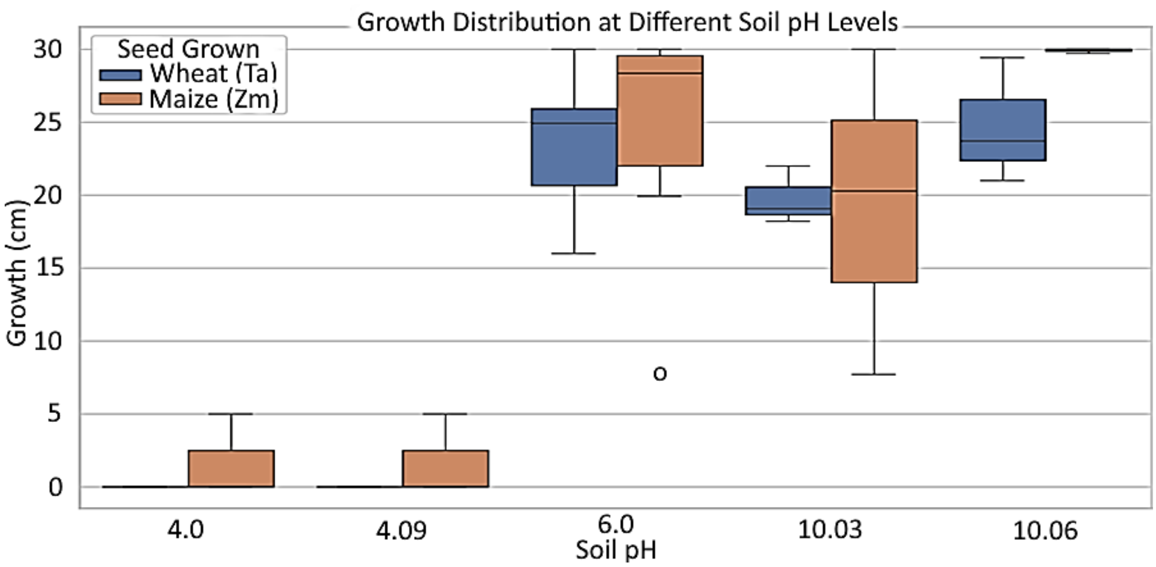

Figure 3. Box plot: Growth distribution at different soil pH levels.

The boxplot in Figure 3 reveals that growth is most stable and consistent at neutral pH (~6.0), with less variability and higher median growth. In contrast, extreme pH levels (4.0 and 10.0) show greater variation and lower median growth, indicating that highly acidic or alkaline conditions negatively impact plant development. The presence of outliers in both acidic and alkaline pH suggests that some plants struggled significantly under these conditions, reinforcing the importance of maintaining a balanced soil pH for optimal growth.

Our results for maize are similar to those found in the soils of Nigeria [16] and Thailand [17]. Additionally, our results for wheat are similar to those found in Mexican soils [14]. A study conducted in China to investigate the effect of alkaline and saline soils on wheat production yielded results similar to those reported in our study. Saline soil inhibits the process of photosynthesis in wheat by decreasing chlorophyll content and also induces ion toxicity [15].

CONCLUSIONS

Based on the findings, it can be concluded that extremely acidic soil (pH 4.000) is detrimental to the vegetative growth of wheat and maize plants (sown in soils of India). A neutral pH (around 6.000) appears to be more favorable for their growth. Slightly alkaline soil could also yield positive results, but the soil should not be saline, as saline and highly alkaline soils are detrimental to wheat growth. It is essential to note that this conclusion is specific to the wheat and maize plants studied and may not apply to other plant species. Furthermore, additional research could investigate the exact mechanisms by which soil pH affects the growth of wheat and maize plants, as well as potential mitigation strategies to enhance plant performance in acidic soil conditions. Therefore, it is essential to maintain the appropriate soil pH range to ensure optimal crop growth and productivity. Regular soil testing and implementing appropriate soil management practices can help support the optimal soil pH range and enhance crop productivity. The pH level of the soil has a significant impact on the growth and yield of wheat and maize crops. The results of this experiment can help farmers and agricultural scientists understand the importance of soil pH and take appropriate measures to maintain the ideal pH level for optimal crop growth and yield.

Availability of Data and Materials

Data will be shared upon request by the readers.

Authors' Contributions

A.S.: Conceptualization and writing of original draft; A.V.: Data analysis; R.A.: Writing, reviewing, and editing, supervision.

Declaration of Competing Interest

The authors declare that they have no known competing interests.

Acknowledgment

Special thanks to Shivaji College for providing the necessary resources, including laboratory facilities and equipment. We would also like to acknowledge DBT sponsored Star College Scheme of the College for their financial support, which made this research possible. The authors acknowledge the contribution of students, Umang, Priyal Angra, Kalash Gupta, Prerna, Kanika, Gauri Bansal, Neetu Yadav, Manita, Vikram Choudhary, Prachi, Namami Bharati, Devesh Shukla, Roshan, Anand Kumar Pandey, Sumit Sharma, Princi Singh, Anjalika, in preliminary studies.

REFERENCES

1. Futa B, Gmitrowicz-Iwan J, Skersienė A, Šlepetienė A, Parašotas I. Innovative soil management strategies for sustainable agriculture. Sustainability. 2024 Oct 31;16(21):9481.
2. Gentili R, Ambrosini R, Montagnani C, Caronni S, Citterio S. Effect of soil pH on the growth, reproductive investment and pollen allergenicity of Ambrosia artemisiifolia L. Front Plant Sci. 2018 Sep 20;9:1335.
3. Prabhudev SH, Ravindra KN, Supreetha BH, Nithyanandha KR, Dharmappa KK, Giresha AS. Effect of soil pH on plants growth, phytochemical contents and their antioxidant activity. J Adv Appl Sci Res. 2023 Sep 14;5(5).
4. Miller JO. Soil pH affects nutrient availability [Internet]. University of Maryland Extension; 2016 [updated 2021 Dec; cited 2025 May 19]. Available from: https://extension.umd.edu/sites/extension.umd.edu/files/publications/FS-1054%20Soil%20pH%20and%20Nutrient%20Availbility_Update_12_2021.pdf
5. O'Kennedy S. Soil pH and its impact on nutrient availability and crop growth. Int J Geogr Geol Environ. 2022;4:236–8.
6. Hinsinger P, Bengough AG, Vetterlein D, Young IM. Rhizosphere: biophysics, biogeochemistry and ecological relevance. Plant Soil. 2009;321:117–52.
7. FAOSTAT. Crops [Internet]. 2023 [cited 2025 May 19]. Available from: https://www.fao.org/faostat/en/#data/QCL/visualize.
8. ul Shahid Z, Ali M, Shahzad K, Danish S, Alharbi SA, Ansari MJ. Enhancing maize productivity by mitigating alkaline soil challenges through acidified biochar and wastewater irrigation. Sci Rep. 2023 Nov 27;13(1):20800.
9. Ngoune Tandzi L, Mutengwa CS, Ngonkeu EL, Gracen V. Breeding maize for tolerance to acidic soils: A review. Agronomy. 2018 May 29;8(6):84.
10. Addisu A, Molla E, Dereje G. Responses of soil properties and yield of bread wheat to compost and lime application on acidic soils of Banja district Northwestern Ethiopia. Discover Agric. 2025 Dec;3(1):1–5.
11. Kumar A, Singh S, Gaurav AK, Srivastava S, Verma JP. Plant growth-promoting bacteria: biological tools for the mitigation of salinity stress in plants. Front Microbiol. 2020 Jul 7;11:1216.
12. Khatun M, Shuvo MA, Salam MT, Rahman SH. Effect of organic amendments on soil salinity and the growth of maize (Zea mays L.). Plant Sci Today. 2019 Apr 1;6(2):106–11.
13. Zörb C, Geilfus CM, Dietz KJ. Salinity and crop yield. Plant Biol. 2019 Jan;21:31–8.
14. Limon-Ortega A, Martinez-Cruz E. Effects of soil pH on wheat grain yield and quality. Commun Soil Sci Plant Anal. 2014 Mar 9;45(5):581–91.
15. Liu D, Ma Y, Rui M, Lv X, Chen R, Chen X, et al. Is high pH the key factor of alkali stress on plant growth and physiology? A case study with wheat (Triticum aestivum L.) seedlings. Agronomy. 2022 Jul 31;12(8):1820.
16. Nwite JN, Ajana AJ, Alinchi I. Effect of pH on soil chemical properties and maize performance in Abakaliki, Nigeria. Agric Sci Digest Res J. 2022;42(3):337–40.
17. Sirisuntornlak N, Ullah H, Sonjaroon W, Anusontpornperm S, Arirob W, Datta A. Interactive effects of silicon and soil pH on growth, yield and nutrient uptake of maize. Silicon. 2021 Feb;13(2):289–99.