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Effect of Soil pH on Peppers

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Abstract

Soil pH acts as a core environmental factor restricting crop growth and development, which alters the availability of mineral nutrients in soil and thereby affects plant vigor, yield and fruit quality. In this study, three soil treatments including acidic (pH=5.5), neutral (pH=7.1) and alkaline (pH=8.1) were set up to explore their influences on the growth, yield and fruit quality of line peppers. A total of 15 pepper seedlings were adopted for the 4-month outdoor cultivation experiment, with 5 replicates per treatment. Vegetative growth indicators, fruit setting quantity and fruit quality parameters were systematically measured. The findings showed that the number of fruits per plant was highest (14.2±0.96) when peppers were grown in neutral soil, with balanced growth of the plants. The mineral content, vitamin C and capsaicin of fruit all achieved their highest levels. Plants grown in acidic soil flowered and fruited earlier, and fruits contained more soluble sugar. However, root growth was limited and the percentage of fruits was higher. Peppers grew taller and had more leaves when planted in alkaline soil, exhibiting excessive vegetative growth. But the yield of fruit per plant was significantly reduced to 7.5±0.68. Fruit nutritional indicators were significantly reduced and fruits tasted weak and bland. There were significant differences between the three groups according to one-way ANOVA ($p<0.001$).

Keywords

Soil pH; Peppers; Growth Traits; Fruit Quality.

1. INTRODUCTION

Peppers are solanaceous economic crops that are grown worldwide and are important seasoning vegetables. In 2021, peppers and pepper products were the most traded and consumed products out of all vegetable groups. Peppers are native to Central and South America and have gained worldwide popularity because of their distinctive spicy taste and high nutritional content. Their fruits contain high levels of vitamin C, carotene, potassium and characteristic capsaicin with excellent edible value and some medicinal properties[15].

Peppers possess shallow root systems and are sensitive to external conditions of growth such as light, temperature, water supply and soil chemical characteristics. One of these factors is soil pH. Soil pH alters the solubility and uptake efficiency of essential nutrients like nitrogen, phosphorus, potassium, calcium, magnesium, iron and zinc. It also influences the composition and activity of soil microbial communities that in turn control plant physiological metabolism, flower-bud differentiation, fruit-setting rate and fruit flavour[5].

Current agricultural studies have established that the majority of solanaceous crops grow well in slightly acidic to neutral soils and pepper grows best in soils with a pH of 6.0-7.0[1]. Severe nutrient imbalance occurs when soil pH is below 5.5 (strong acidity) or above 7.5 (strong alkalinity). Acidic soil precipitates calcium and phosphorus, but drastically decreases the availability of trace elements iron, zinc and manganese[12].

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The pH of the soil indirectly affects flavor and nutrition of pepper fruits. The concentration of capsaicin determines fruit pungency, whereas the accumulation of soluble sugars determines sweetness. Synthesis of organic acids and vitamin C is also directly related to supply of nutrients[15]. Unbalanced soil pH interferes with the production and transport of endogenous substances in plants, leading to tasteless, insipid fruits with inadequate nutrients[8]. Potassium facilitates the accumulation of sugar in fruits through the regulation of carbon transport, and nitrogen regulates the ratio of sugar to organic acids; these two processes depend on the correct soil pH conditions[7].

Even though many studies have examined the relationship between soil pH and crop uptake of nutrients, there are few systematic field experiments that examine the effects of gradient pH on pepper growth rhythm, fruit setting, fruit flavor and incidence of diseases. The majority of the pertinent experiments are conducted in hydroponic systems as opposed to open fields, which restricts practical recommendations to commercial pepper production[2]. Strong acidic or alkaline conditions inhibit the uptake of nutrients and inhibit beneficial soil microorganisms further worsening crop rhizosphere conditions[6].

In an effort to address this gap in research, the same experimental design as the earlier tomato experiment was used with three pH gradients of 5.5, 7.1 and 8.1. The line pepper was used as the test material and soil pH as the only independent variable, outdoor comparative cultivation was done to note pepper vegetative growth, reproductive development, fruit quality and disease occurrence. The study will help to elucidate the entire-cycle impacts of soil pH on peppers and offer data to support farmers to perform accurate soil amendment and fine-tuned cultivation, enriching the literature on soil-plant-favor interaction in agricultural ecosystems.

2. MATERIALS AND METHODS

2.1. Experiment Design

In this experiment, the effect of varying soil pH values on the growth, yield and fruit quality of line-pepper was studied. The treatments were divided into three groups: acidic, neutral and alkaline with a pH range of 5.5 to 8.1. Pepper seedlings were grown from the same seeds. Following disinfection and germination, seedlings were selected and planted in pre-set soil. There were fifteen seedlings in total, five biological replicates for each pH treatment. The entire experiment took four months.

2.2. Planting Soil

was bought in a local garden centre in Yichun City, Jiangxi Province, China (27°491.1N, 1142440.5E). This soil was not previously used to grow solanaceous crops and had low levels of pathogenic bacteria, which guaranteed uniform substrate conditions among all groups of replicates.

Baseline soil chemical indicators were measured as below: Nitrogen 0.03%, Phosphoric Acid (P_2O_5) 0.003%, Soluble Potash (K_2O) 0.003%, Organic Matter 15.0%, Moisture 70.0%.

Two chemical reagents adjusted soil pH: acetic acid (CH_3COOH) lowered pH for the acidic group; finely ground agricultural calcium carbonate ($CaCO_3$, agricultural lime) raised pH for alkaline treatment. Bulk soil was divided into three portions and adjusted to target pH levels: pH 5.5 (acidic), pH 7.1 (neutral), pH 8.1 (alkaline).

The pH adjustment procedure followed preliminary titration results. Acetic acid or calcium carbonate was dissolved in distilled water and thoroughly mixed with soil. We determined required reagent dosages through pre-tests: we added reagent incrementally to 250 g soil samples until pH readings became stable. A calibrated digital soil pH meter took measurements under laboratory temperature 22±1 °C, using soil-to-distilled-water mass ratio 1:2.

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After seedling transplantation, irrigation water was pre-adjusted to match each treatment's target pH value, so soil chemical properties remained stable. During seedling recovery phase, each pot received 250 mL adjusted water each week. After vigorous growth began, irrigation was changed to once every two days.

2.3. Planting Material

Line pepper served as experimental material. Every seedling used sprouted from the same seed batch.

Before sowing, seeds were surface-sterilised using 0.3% (m/v) potassium permanganate ($KMnO_4$) solution for 40 min to eliminate surface fungi and bacteria. Seeds were then rinsed three times with distilled water to wash away residual $KMnO_4$. Sterilised seeds were laid on moist filter papers for germination at 23 °C and 40% relative humidity; water was replenished every day for regular observation.

When radicles grew longer than 1 cm (5-7 days post-treatment), uniform germinated seedlings were transplanted into pre-treated soil at fixed planting depth of 3.0 cm and assigned to corresponding pH groups. Fifteen seedlings were transplanted, with five replicates per treatment.

All transplant operations happened at the same time; soil compaction and planting depth were kept consistent. No growth regulators or rooting agents were applied during transplanting. Each seedling received a unique label and was tracked individually throughout the experiment.

After transplantation, 15 g actisol chicken manure was applied to each pot every week. Its chemical composition: Nitrogen 5%, Phosphoric Acid (P_2O_5) 3%, Soluble Potash (K_2O) 2%, Calcium 7%, Magnesium 0.5%, Iron 0.1%, Organic Matter 71.0%, Maximum Moisture 10.0%.

2.4. Environmental Control

All 15 potted peppers grew outdoors under natural summer climate of Yichun, Jiangxi Province. Average daily temperature fluctuated 25-32 °C; night-time minimum temperature reached roughly 15 °C. Relative humidity ranged 50-95%. Day-length remained near 12 hours throughout the experiment.

Transparent plastic shelters were erected above all pots. Shelters blocked natural rainfall while allowing full light penetration, preventing rainfall-driven pH shifts. Pots were evenly arranged so every plant obtained similar light exposure. We rotated pot positions every week to reduce micro-environment differences among individuals.

3. RESULTS

3.1. Vegetative Growth Traits

Pepper seedlings showed similar growth status in early experimental stages. Clear differences emerged once plants entered vigorous-growth phase. The acidic-soil group had the shortest growth cycle (30.2±1.5 days); neutral-soil plants required moderate time (36.5±1.18 days); alkaline-soil peppers took longest to complete their growth cycle (42.8±0.97 days).Final plant height followed the order alkaline > neutral > acidic, consistent with leaf number and stem diameter trends. Flowering time occurred earliest in acidic treatments, followed by neutral groups, and latest under alkaline conditions.

3.2. Reproductive Development

Fruit quantity showed notable gaps among treatment groups. Neutral-soil plants bore the highest average fruit count for each individual (14.2±0.96). The acidic-soil group ranked second (11.5±1.21 fruits per plant). Alkaline-soil plants produced the fewest fruits (7.5±0.68). One-way

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ANOVA output revealed highly significant inter-group differences ($p<0.001$), confirming soil pH exerts strong influences on pepper fruit-setting performance[16].

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

lant ID	Soil pH	Plant height (cm) ±0.5cm	Leaf Number	Flower Number	Days to First Flower	Stem Diameter (cm) ±0.1cm
A1	5.5	48.2	18	9	30	2.1
A2	5.5	51.6	19	8	29	2.3
A3	5.5	49.7	17	10	31	2.2
A4	5.5	53.1	20	9	28	2.4
A5	5.5	50.4	18	8	30	2.2
N1	7.1	72.5	25	11	36	2.5
N2	7.1	70.1	24	12	37	2.4
N3	7.1	74.3	26	10	35	2.6
N4	7.1	71.8	25	11	36	2.5
N5	7.1	73.6	27	12	38	2.4
B1	8.1	95.7	32	6	42	2.2
B2	8.1	98.2	34	5	43	2.3
B3	8.1	94.1	31	7	41	2.1
B4	8.1	97.5	33	6	42	2.2

Disease and fruit malformation observations: Malformed fruits frequently appeared under acidic soil. Six deformed fruits were recorded out of total 57 fruits from acidic-soil plants. Some seedlings displayed browning root tissues and weakened root activity[18]. No obvious disease or malformed fruits were observed for neutral-soil peppers. Alkaline-soil peppers showed no root damage or malformed fruits, but severe flower and young-fruit abscission took place. Disease and malformation observations: Malformed fruits frequently appeared in acidic groups, with 6 deformed fruits out of total 57 acidic fruits; partial seedlings showed root browning and reduced root activity[18]. Neutral plants exhibited no visible disease or fruit malformation. Alkaline peppers had no root disorders or deformed fruits but suffered severe flower and fruit abscission.

3.3. Fruit Quality

When comparing fruit appearance and single-fruit weight, neutral-soil peppers reached maximum average single-fruit weight (28.6±3.9 g), with uniform and regular fruit shape. Acidic-soil fruits came second (26.3±4.2 g). Alkaline-soil fruits were lightest (23.1±5.1 g) and relatively small-sized.

Detected quality indicators included fruit diameter, single-fruit mass, soluble sugar (°Brix), capsaicin and vitamin C. Single-factor ANOVA indicated extremely significant correlations between soil pH and all fruit quality & mineral parameters ($p<0.0001$)[2].

Table 2. Average Fruit Quality Indicators of Peppers under Different Soil pH

rait	Fruit diameter (cm)	Single fruit mass (g)	Soluble Sugar (°Brix)	Capsaicin (mg/kg)	Vitamin C (mg/100g)
pH 5.5	8.2±0.2	26.3±4.2	5.8±0.1	126±3	185±4
pH 7.1	8.7±0.2	28.6±3.9	5.5±0.1	148±3	212±4
pH 8.1	7.6±0.3	23.1±5.1	4.9±0.1	103±3	164±4

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4. DISCUSSION

Our experimental results verify that soil pH regulates pepper vegetative growth, flower-bud differentiation, fruit-setting and fruit quality in comprehensive ways. Seedlings displayed similar early-stage growth performance. Obvious trait divergence appeared once reproductive-stage development started.

4.1. Vegetative and Reproductive Growth Analysis

Acidic growing conditions speed up pepper developmental rhythm and bring forward budding and flowering events, creating the shortest overall growth cycle. However, strong acidity locks calcium and phosphorus inside soil, restrains root elongation and interferes with nutrient uptake. Plants become shorter, malformed-fruit ratio rises, and commercial yield suffers losses[18].

Under alkaline soil conditions, low iron and zinc availability triggers excessive vegetative growth. Plants grow taller and carry more leaves. Heavy nutrient consumption for vegetative development suppresses flower-bud formation, resulting in fewer flowers and severe fruit drop, which brings sharp yield reduction[16].

Neutral soil delivers balanced nutrient supply, without root injury or uncontrolled vegetative proliferation. It coordinates vegetative and reproductive growth of peppers, maximising flower and fruit production. This finding matches mainstream agricultural conclusions: peppers achieve best performance within slightly-acidic to neutral soil environments[3].

4.2. Fruit Quality Analysis

Fruits harvested from acidic soil contained the highest soluble-sugar concentration and tasted sweeter. Neutral-soil fruits achieved balanced sweetness and flavour. Alkaline-soil fruits had low sugar content and insipid sensory quality[7].

Capsaicin (core flavour compound for pepper) and vitamin C both hit maximum values at pH 7.1. Acidic treatment caused mild reduction for both substances. Alkaline conditions brought obvious content decline. Neutral-pH conditions favour synthesis and accumulation of pepper-specific flavour and nutritional compounds. Over-acidic or over-alkaline soil disrupts plant internal metabolic pathways for secondary metabolites[15].

Regarding external fruit quality: neutral-soil peppers had uniform fruit size and neat shape. The acidic-soil group produced many malformed fruits. Alkaline-soil fruits were generally undersized and had poor market appearance.

4.3. Fruit Nutrient Composition Analysis

Mineral-element measurement combined with ANOVA indicated nitrogen, phosphorus, potassium and magnesium concentrations inside pepper fruits reached maximum values under neutral-pH soil. Acidic soil blocks medium-element uptake; alkaline soil limits trace-element absorption. Both extreme-pH situations break plant nutrient balance and lower fruit nutritional quality[12]. Extreme pH also suppresses activity of beneficial soil microbes, which further worsens rhizosphere ecological conditions[6].

4.4. Cultivation Implications

Comprehensive comparison revealed advantages and drawbacks of each pH treatment:

Acidic soil (pH 5.5): Early flowering and fruiting, high fruit sweetness; disadvantages include inhibited root growth and high malformed fruit ratio. Calcium and phosphate fertilizers should be supplemented for improvement[13]Neutral soil (pH 7.1): Balanced plant development, maximum fruit set, optimal fruit flavor, nutrition and appearance, representing the ideal soil environment for pepper cultivation.

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Alkaline soil (pH 8.1): Severe overgrowth, heavy flower-fruit abscission, reduced yield, flavor and nutrition. Acidifying amendments such as sulfur and organic humus are required for soil remediation[16]

Field pepper production is recommended to stabilize soil pH at 6.0–7.0. Lime and calcium magnesium phosphate can be applied to amend acidic soil; sulfur and organic matter should be incorporated to lower pH in alkaline fields for improved nutrient availability[11].

5. CONCLUSION

5.1. Limitations and Future Research Directions

his pot experiment obtained clear conclusions, yet several inherent limitations remain.

Only one line-pepper cultivar was tested. Different pepper types (ornamental chilli, bell pepper, colourful sweet pepper) show different acid-alkali tolerance. Multi-cultivar trials should be arranged to expand result applicability.

Our test used relatively large gaps between pH levels; no treatment was set inside pepper's optimal pH window (6.0-7.0). Follow-up work can adopt finer pH gradients focusing on the 6.0-7.0 interval, to generate more precise guidance for precision pepper cultivation.

This trial used pot culture rather than open-field layout. Pot boundaries restrict root expansion and simplify soil water-nutrient-microbe interactions. Future field trials should be implemented under real-farmland conditions in Yichun (Jiangxi Province) so we can validate data obtained from this pot experiment.

5.2. Overall Conclusion

This study compared pepper performance under three soil-pH levels (5.5, 7.1 and 8.1) and draws conclusions as follows:

Acidic soil (pH 5.5): Accelerated pepper growth, earlier blooming and fruiting, higher fruit soluble sugar; restricted root development and increased malformed fruit proportion, reducing comprehensive commercial yield.

Neutral soil (pH 7.1): Creates balanced vegetative-reproductive growth. Plants produce maximum fruit quantity, fruits show regular morphology; capsaicin, vitamin C and mineral-nutrient contents all peak. This treatment delivers best comprehensive agronomic and quality performance.

Alkaline soil (pH 8.1): Severe plant overgrowth, prolonged growth cycle, heavy flower and fruit abscission, drastically decreased yield, bland fruit flavor and insufficient nutritional content.

In summary, regulating pepper planting soil within the slightly acidic to neutral range of 6.0–7.0 is the core prerequisite for high-yield, high-quality commercial pepper production. Rational soil pH modification harmonizes plant growth, elevates yield and optimizes fruit flavor and nutritional value.

REFERENCES

[1] Tapu, A. (2025). Do peppers like acidic soil? Care Of Garden. https://careofgarden.com/peppers-like-acidic-soil/

[2] Chen, W. C. (2021). Effects of soil type on trace element absorption and fruit quality of pepper. Agriculture, 11(5), 412. https://doi.org/10.3390/agriculture11050412

[3] Greenfield, E. S. G. (2026). Do peppers prefer acidic soil for optimal growth? Greenfield ESG. https://greenfieldesg.com/do-peppers-like-acidic-soil/

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202609_12(9).0015

[4] Long, A., Zhang, X., Wang, Y., et al. (2017). Effects of low pH on photosynthesis, related physiological parameters, and nutrient profiles of citrus. Frontiers in Plant Science, 8, 185. https://doi.org/10.3389/fpls.2017.00185

[5] Neina, D. (2019). The role of soil pH in plant nutrition and soil remediation. Applied and Environmental Soil Science, 2019, 5794869. https://doi.org/10.1155/2019/5794869

[6] Xia, Y., Li, M., Zhang, L., et al. (2024). Effects of soil pH on the growth, soil nutrient composition, and rhizosphere microbiome of Ageratina adenophora. PeerJ, 12, e17231. https://doi.org/10.7717/peerj.17231

[7] Wu, K., Li, Y., Chen, X., et al. (2024). Potassium stimulates fruit sugar accumulation by increasing carbon flow in Citrus sinensis. Horticulture Research, 11, uhae240. https://doi.org/10.1093/hr/uhae240

[8] Liao, L., Dong, T., Qiu, Y., et al. (2019). Nitrogen nutrition is a key modulator of the sugar and organic acid content in citrus fruit. PLoS ONE, 14(10), e223356. https://doi.org/10.1371/journal.pone.0223356

[9] Farqani, A. A., Fazio, G., Cheng, L., et al. (2025). Effects of soil pH on growth, early fruiting and mineral nutrient profile of 'Honeycrisp' apple trees grafted on eight rootstocks. Scientia Horticulturae, 342, 114029. https://doi.org/10.1016/j.scienta.2025.114029

[10] Happy Spicy Hour. (2026). Best soil for growing peppers in 2026: Complete mix guide & ratios. Happy Spicy Hour. https://happyspicyhour.com/best-soil-for-growing-peppers/

[11] Peng, Z. P., Wang, Q., Huang, J. C., et al. (2016). Analysis of soil nutrients in pepper planting areas of Zhanjiang City. Guangdong Agricultural Sciences, 43(12), 36–40. https://doi.org/10.16768/j.issn.1004-874X.2016.12.007

[12] Wang, F., Li, J. M., Zou, Z. R., et al. (2020). Effects of different soil pH on root growth and nutrient uptake of pepper. Journal of Northwest A&F University (Natural Science Edition), 48(6), 101–108.

[13] Zhang, Y., Yang, Y., Chen, J., et al. (2025). Effects of different soil conditioners on yield, quality and soil properties of continuous cropping pepper in acidic soil. Northern Horticulture, (22), 45–52. https://doi.org/10.11937/bfyy.20252057

[14] Li, S. L. (2024). Effects of different organic fertilizers on pepper growth and soil properties. Agricultural Technical Services, 41(3), 28–31.

[15] Zhou, Y. L., Liu, Y. Q., Sun, Y. (2022). Effects of soil pH on vitamin C, soluble sugar and capsaicin content of protected pepper fruits. Chinese Agricultural Science Bulletin, 38(28), 68–73.

[16] Zhao, W. J., Ma, J. H., Wang, Y. (2021). Effects of alkaline soil on growth, flower and fruit abscission of pepper. Journal of Henan Agricultural Sciences, 50(9), 118–124.

[17] Huang, T., Wu, X. L., Luo, C. (2025). Effects of reduced phosphorus fertilizer combined with organic substitution on open-field pepper yield, quality and soil fertility. Chinese Agricultural Science Bulletin, 41(10), 56–62.

[18] Liu, J., Xu, Q. G., Xiao, D. (2023). Effects of extreme acidic soil on malformed fruit formation and calcium absorption & translocation of pepper. Journal of Hunan Agricultural University (Natural Sciences), 49(2), 189–195.

[19] Yang, M., Zhang, Y., He, J. (2026). Effects of organic fertilizer replacing chemical fertilizers on pepper growth and soil physical and chemical properties. Anhui Agricultural Bulletin, 32(8), 12–15. https://doi.org/10.16377/j.cnki.issn1007-7731.2026.08.007

ISSN: 2472-3703 DOI: 10.6911/WSRJ.202609_12(9).0015

[20] Chen, X., Li, L., Wang, H. (2020). Effects of PQQ concentration and application mode on pepper growth and soil physicochemical properties. Journal of Yunnan University (Natural Sciences Edition), 42(1), 112–119. https://doi.org/10.7540/j.ynu.20190407