Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

Effect of Soil pH on Growth of Some Medicinal Plants

Surya Mani Kumar

Professor and Principal in-charge, R. J. M. College, Saharsa 852201, Bihar, India

Abstract. Medicinal plants have been valuable sources of natural therapeutic compounds leading to increased attention and recognition of their importance in healthcare, pharmaceutical production, and sustainable agriculture due to their contributions in these areas. Soil pH is of great significance among the environmental factors that impact the cultivation of medicinal plants as this factor plays a crucial role in determining the availability of nutrients and the functioning of microbial processes that include root development and processes impacting the plant growth and accumulation of the bioactive substances. Soil pH management becomes the prerequisite for wise decision-making and ensuring the successful production of the necessary medicinal plants. The present review provides a thorough review of the impact of soil pH on several medicinal plants by discussing the findings from the modern literature. It is important to understand that the current research employs a literary comparative method exploring the influence of neutral, acidic, and alkaline soils on the plant's development, nutrient uptake, photosynthesis and soil microorganisms, as well as productive capacity and phytochemical characteristics of the plant. The results of the research indicate that soil pH has an impact on nutrient availability and the rhizosphere microbial patterns, as well as its impact.

Keywords: Soil pH, Medicinal Plants, Plant Growth, Nutrient Availability, Soil Fertility, Phytochemicals, Sustainable Agriculture.

1. Introduction

Medicinal plants are high valued from ancient times and are also believed as an integral part of conventional medicine and modern pharmaceutical. The active ingredients are naturally occurring chemical compounds such as alkaloids, terpenoids, phenolics, flavonoids, essential oils, etc. [1]. The growing interest in herbal medicine and sustainable healthcare has led to increased planting of medicinal plants in various shared climatic regions. Medicinal plants require proper environmental and soil conditions for a healthy yield. Soil offers a firm medium to support plant bodies and supply water, nutrients and oxygen. Plant growth and development are consequently greatly influenced by the physicochemical characteristics of the soil. The pH of the soil should be kept at its ideal level throughout plant growth and development because it influences the availability of nutrients and other necessary elements. The availability of nitrogen, phosphorus, potassium, iron, zinc, calcium, and magnesium is decreased in extremely acidic or alkaline soils, which consequently restricts the growth and development of medicinal plants. Plants that are malnourished produce less biomass and have a detrimental impact on the synthesis of secondary metabolites. Besides the supply of plant nutrients, pH influences the activity of microorganisms in the rhizosphere, which results in enhanced nutrient cycling and availability, decomposition of organic matter and suppression of diseases. Variation of pH affects the general physiology and ecology of medicinal plants and lessens their resistance to pests, pathogens and environmental stresses. The answer of medicinal plants to soil pH depends on their organic makeup and nutritional requirement. Most previous research on the relationship between soil pH and agricultural crops has been conducted on an individual basis [2]. Little is known about the overall effect of soil pH on different species of medicinal plants.

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

2. Literature Review

Recent studies have showed us that the growth of medicinal plants is effected by soil properties and environment [2]. It also shows us that better management practices improve the quality and productivity of plants. Research has also showed the value of soil pH, microbial interactions, and sustainable cultivation techniques for medicinal plant productivity [3].

2.1 Influence of Soil pH on Medicinal Plant Growth

The pH of the soil is an important factor for the growth and development of medicinal plants. An optimum range of pH helps attain nutrient uptake in plants and promote their growth and development [4]. Also alkaline soils reduce the nutrients availability to plants in results in poor growth, yield, and biomass production. Medicinal plants species have different levels of tolerance to soil pH because of their nutritional and developmental demands. For example, *Melissa officinalis* and *Ocimum basilicum* had a better photosynthetic performance in comparison to Cassia angustifolia because it has better biomass production and build-up of medicinal compounds which have improved soil pH. The experiments which were being conducted on *Panax notoginseng* elaborated that adjusting the soil pH from highly acidic levels which improves the plant growth by reducing the incidence of soil-borne diseases and improving the soil's overall properties [5]. These findings are sufficient proof to support for better medicinal plant production.

2.2 Soil pH, Plant Physiology and Nutrient Availability

Soil pH is an important parameter that regulates the availability of macro and micronutrients affecting the physio-logical efficiency of the plant. Imbalance in soil pH affects the availability of phosphorus, iron, zinc, calcium, magnesium, and potassium resulting in poor chlorophyll synthesis, root formation, and photo-synthesis processes . Thus, soil pH affects nutrient availability, crop yield, and metabolite production for medicinal purposes. It has been reported that the inclusion of biochar and beneficial microorganisms can maintain favourable soil pH levels which improves the availability of nutrients [6].

2.3 Sustainable Soil Management Strategies for Medicinal Plant Cultivation

The use of organic materials, biochar, microorganism inoculation, and liming is very useful in soil improvement by raising the soil pH, fertility, and nutrients for the cultivation of medicinal plants [6]. Biochar application increases soil enzyme activity, root development, and photosynthesis in various cultivation conditions. Also, biochar application makes the soil condition better and improves tolerance of salt [7]. Similarly, beneficial microorganisms make the soil structure better and improve stress resistance with enhanced yields of medicinal plants.

Table 1. Studies on Soil pH and Medicinal Plants

Plant Species	Research Focus	Key Finding
Ocimum basilicum	Soil pH	Photosynthesis improved near neutral pH

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

Cassia angustifolia	Soil fertility	Biomass and bioactive compounds increased
Panax notoginseng	Soil acidification	Disease incidence decreased after pH improvement
Aloe vera	Soil acidification	Better salinity tolerance and soil quality
Mentha longifolia	Biochar amendment	Growth varied significantly across different soils

3. Methodology

Here we review the published research on soil pH, nutrient availability, microbial interactions and cultivation of medicinal plants [8]. It shows the influence of these factors on growth of plants and results of cultivation.

3.1 Research Design

The present study was conducted using the systematic literature review method to determine the influence of the soil pH on the growth and development of medicinal plants. Instead of conducting laboratory and field experiments, the current research utilized peer-review scientific articles to evaluate the influence of the independent variable (soil pH) on the dependent variables (nutrients, plant's physiology, and productivity). The study involved a comprehensive comparison of the results of previous research and aimed to identify the strengths and weaknesses of the prior studies, as well as research gaps, to determine the key aspects of the influence of soil pH on medicinal plant growth and development [8].

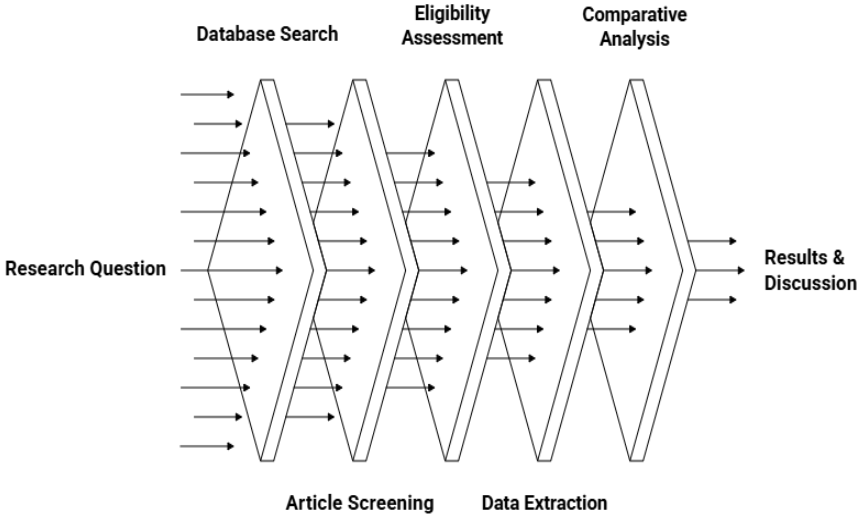

Figure 1. Overall workflow adopted for the systematic literature review

3.2 Data Sources

To conduct the present study, peer-review articles were searched and selected from the world's largest academic search engines, including Google Scholar, PubMed, ScienceDirect, Scopus,

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

as well as SpringerLink. The articles included in the current study were retrieved from various journals, including those specializing in soil science, plant physiology, environmental science, and medicinal plant production. Particular attention was paid to peer-reviewed studies published from 2020 onwards.

3.3 Study Selection

The articles included in this study were selected according to strict inclusion and exclusion criteria.

Inclusion Criteria

- Peer-viewed articles or review papers.
- The year of publication – 2020 onwards.
- Articles researching the connection between the pH level of the soil and medicinal plants.
- Articles discussing the impact of soil pH on plant growth and development, the content of phytochemicals in plants, soil fertility, and the interaction with microorganisms.
- Articles published in English.

Exclusion Criteria

- Removed duplicates.
- Excluded articles that have not been through peer-review.
- Excluded conference abstracts that do not contain scientific information.
- Excluded articles that do not address medicinal plants or the connection between plants and pH.
- Excluded articles that do not report experiments or results.

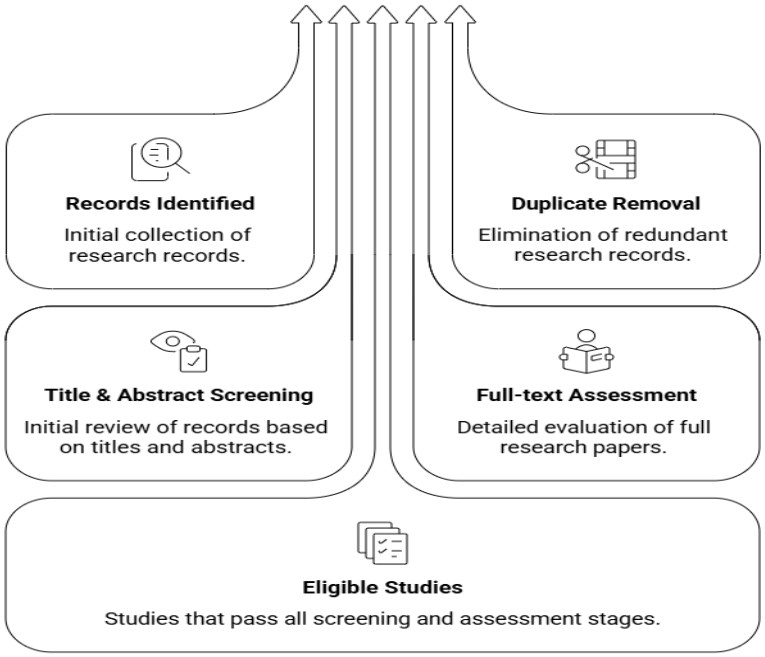

Figure 2. PRISMA-Style Flow Diagram

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

3.4 Data Extraction

We developed a standardized format for data extraction to ensure that we extracted the same information from each study we reviewed. The following variables were abstracted and placed into a table:

- Plant species with medicinal properties
- pH range of soil
- Type of soil
- Growth factors
- Nutrient absorption
- Biomass production
- Seed germination
- Crop yield
- Phytochemical or secondary metabolite content

Key findings:

Data were presented in comparative matrices for systematic evaluation and to minimize inconsistencies in data interpretation.

3.5 Comparative Analysis

The studies included were classified based on the medicinal plant species, soil pH categories (acidic, neutral, and alkaline), nutrient dynamics, physiological responses, and sustainable soil management practices. A comparative analysis was done to find similarities and differences of published results. Particular emphasis was given to the effects of soil pH on the availability of nutrients, root morphology, microbial diversity, photosynthetic efficiency, biomass production and phytochemical synthesis. The compiled evidence was analyzed for common trends, present research gaps and knowledge gaps to direct the future research on sustainable cultivation of medicinal plants [8].

4. Results And Discussion

The reviewed studies indicate that soil attributes, farming methods and microbial activity have a strong effect on growth and quality of medicinal plants. They also point to species-exclusive responses and the value of sustainable soil management in improving cultivation results [9] .

4.1 Factors Influencing Vegetation Recovery

Most species grew best at near-neutral pH (6.0–7.5) when conditions in the rhizosphere and nutrient uptake were most favourable. Both acidic and alkaline soils reduced plant growth through disturbance of the availability and uptake of nutrients. It is important to maintain the optimal soil pH for healthy plant metabolism. Responses of the plant species differed. *Ocimum basilicum* and *Cassia angustifolia* were found to grow better in suitable soil conditions . The growth of *Panax notoginseng*, *Aloe vera* and medicinal mint was also improved by soil pH management. The optimum soil pH is important for the growth of medicinal plants, nutrient

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

uptake and the quality of the crop. Usually the best conditions are found in near neutral soils [9].

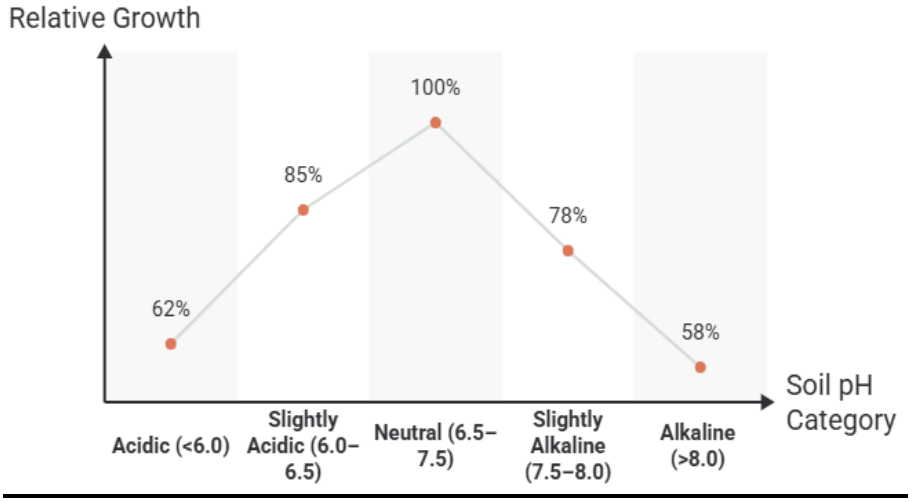

Figure 3. Relative Growth Under Different Soil pH

4.2 Influence of Soil pH on Nutrient Availability

Soil pH also directly affects the growth as well as quality of medicinal plants through controlling the availability of nutrients. Near-neutral soils are conducive to balanced uptake of the necessary nutrients for optimum growth. Acidic soils reduce the availability of phosphorus and increase the toxicity of metals, whereas alkaline soils inhibit the uptake of iron and zinc, limiting plant growth and biomass production . Such imbalances influence the synthesis of bioactive compounds. An optimum soil pH is important for sustainable medicinal plants cultivation as it improves the efficiency of nutrients use, plant productivity and phytochemical accumulation [10].

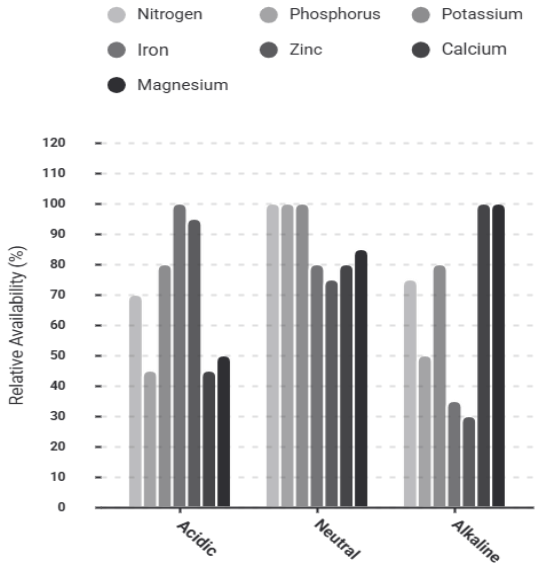

Figure 4. Nutrient Availability Across Soil pH

Annals of R.S.C.B., ISSN:1583-6258, Vol. 26, Issue 1, 2022, Pages. 4643-4651
Received 23 January 2022; Accepted 15 March 2022

4.3 Comparative Analysis of Selected Medicinal Plants

Different medicinal plants answered differently to soil pH because of species-particular nutrient requirements and physiological characteristics [10]. Most species prefer slightly acid to neutral soil (pH 6.0 – 7.5) . Among the selected species, *Ocimum basilicum* and *Cassia angustifolia* showed better growth under balanced soil conditions. Soil pH correction improved the growth of *Panax notoginseng* . Balanced soils supported *Aloe vera* growth and biochar improved growth of medicinal mint through better soil quality . The modification of soil pH for a particular species enhances plant growth, biomass production and phytochemical accumulation, and hence leads to sustainable cultivation [10] .

Table 2. Comparative response of selected medicinal plants to soil pH.

Medicinal Plant	Optimum Soil pH	Growth Response
Ocimum basilicum (Tulsi)	6.5–7.0	Improved biomass and nutrient uptake
Cassia angustifolia (Senna)	6.5–7.5	Increased biomass and phytochemical content
Panax notoginseng	6.0–7.0	Better rhizosphere health and disease resistance
Aloe vera	6.0–7.5	Enhanced vegetative growth
Mentha longifolia (Mint)	6.0–7.0	Improved growth under soil amendments

4.4 Discussion

All the reviewed studies indicated the importance of the optimum soil pH for the growth and productivity of medicinal plants. The optimum pH was species dependent, but in general neutral soils were best. Organic manure and biochar enhance soil pH and nutrient availability, which promote plant growth in poor conditions. Differences in experimental conditions and soil characteristics do not allow a direct comparison among studies, and standardized methods of evaluation are needed. In summary, proper maintenance of soil pH improves progress, nutrient absorption and actinic buildup of medicinal plants. Future work should determine species-exclusive pH requirements and evaluate long-term field performance. Further, soil health can be cured by integrating beneficial microbes and eco-friendly cultivation practices, which can enhance plant productivity.

5. Conclusion

This review aims to emphasize the importance of the soil pH in the growth, yield, and medicinal quality of different medicinal plants. The comparison of the included studies demonstrated that soil pH affects the nutrient supply, root system development, and microorganism activity,

which determines plant growth and physiology. Most of the studied species showed that the optimal growth was achieved at a slightly acidic to neutral soil pH (6.0-7.5) when the plants' demand for nutrients is satisfied and the soil biology is enhanced. The results of the review highlighted the importance of the relationship between soil pH and plant species, which determines the necessity for crop-specific approaches to growing plants in the soil. In this regard, the appropriate soil treatment and pH regulation can ensure the increased nutrient uptake and biomass production in medicinal plants. Thus, the current review demonstrated the importance of maintaining the optimal soil pH for growing medicinal plants. The results of the review can serve as an invaluable source of information for further experimental studies on medicinal plant cultivation as well as help in developing cost-effective and efficient strategies for growing medicinal plants.

6. Future Scope

The results of the review that was conducted have indicated a number of areas that require additional research in order to ensure medicinal plants' sustainability via appropriate soil pH management. Some of the recommendations that were made include:

6.1 Long-Term Field Studies

The conduction of long-term field experiments that will enable researchers to reveal the impact of soil pH in different climatic conditions and soil types on the target plants' growth and phytochemical response.

6.2 Species-Specific Soil pH Optimization

The determination of optimum soil pH in relation to specific plant species in order to secure the best possible biomass and medicinal qualities.

6.3 Sustainable Soil Management

A more accentuated focus on the development of soil management approaches that are oriented towards sustainability, such as the use of biochar, compost, and biofertilizers.

6.4 Integration of Advanced Technologies

An increased use of precision agriculture, sensors, and GIS technologies in order to make soil pH management more efficient.

6.5 Climate-Resilient Cultivation Strategies

The consideration of the impact of soil pH in the context of climate change, as well as the adjustment of nutrient supply and demand in medicinal plants in order to gain a better understanding of how these factors affect plants' overall sustainability.

References

1. Pant, P., Pandey, S., & Dall'Acqua, S., "The Influence of Environmental Conditions on Secondary Metabolites in Medicinal Plants: A Literature Review," *Chemistry & Biodiversity*, vol. 18, no. 11, Art. no. e2100345, 2021. https://onlinelibrary.wiley.com/doi/abs/10.1002/cbdv.202100345

2. Tsai, HH., Schmidt, W. The enigma of environmental pH sensing in plants. *Nat. Plants* **7**, 106–115 (2021). https://doi.org/10.1038/s41477-020-00831-8
3. Gondal, A. H., *et al*., "Influence of Soil pH and Microbes on Mineral Solubility and Plant Nutrition: A Review," *International Journal of Agriculture and Biological Sciences*, vol. 6, no. 2, pp. 71–82, 2021. https://www.academia.edu/download/103682279/Volume_205_20Issue_201_20Paper_208.pdf
4. Fierascu, R. C., Fierascu, I., Baroi, A. M., and Ortan, A., "Selected Aspects Related to Medicinal and Aromatic Plants as Alternative Sources of Bioactive Compounds," *International Journal of Molecular Sciences*, vol. 22, no. 4, Art. no. 1521, 2021, doi: 10.3390/ijms22041521.
5. Zhao, L., *et al*., "Biochar Increases *Panax notoginseng* Survival Under Continuous Cropping by Improving Soil Properties and Microbial Diversity," *Science of the Total Environment*, vol. 850, Art. no. 157963, 2022. https://www.sciencedirect.com/science/article/pii/S0048969722050896
6. Dai, Z., *et al*., "Association of Biochar Properties with Changes in Soil Bacterial, Fungal and Fauna Communities and Nutrient Cycling Processes," *Biochar*, vol. 3, no. 3, pp. 239–254, 2021. https://link.springer.com/article/10.1007/s42773-021-00099-x
7. Msimbira, L. A., & Smith, D. L., "The Roles of Plant Growth-Promoting Microbes in Enhancing Plant Tolerance to Acidity and Alkalinity Stresses," *Frontiers in Sustainable Food Systems*, vol. 4, Art. no. 106, 2020. https://www.frontiersin.org/journals/sustainable-food-systems/articles/10.3389/fsufs.2020.00106/full
8. Page, M. J., McKenzie, J. E., Bossuyt, P. M., *et al*., "The PRISMA 2020 Statement: An Updated Guideline for Reporting Systematic Reviews," *BMJ*, vol. 372, p. n71, 2021. https://www.bmj.com/content/372/bmj.n71.short
9. Sun, Z., Hu, Y., Shi, L., *et al*., "Effects of Biochar on Soil Chemical Properties: A Global Meta-Analysis of Agricultural Soil," *Plant, Soil and Environment*, vol. 68, no. 6, pp. 272–289, 2022, doi: 10.17221/522/2021-PSE. https://pse.agriculturejournals.cz/artkey/pse-202206-0003_effects-of-biochar-on-soil-chemical-properties-a-global-meta-analysis-of-agricultural-soil.php
10. Tesfaye, F., Liu, X., Zheng, J., *et al*., "Could Biochar Amendment Be a Tool to Improve Soil Availability and Plant Uptake of Phosphorus? A Meta-Analysis of Published Experiments," *Environmental Science and Pollution Research*, vol. 28, pp. 34108–34120, 2021, doi: 10.1007/s11356-021-14119-7. https://link.springer.com/article/10.1007/s11356-021-14119-7