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Research Progress on the Effects of Soil Acidity and Alkalinity on Plant Growth

Lichuan Qiu

Beijing No.80 High School, Beijing, China
Email: ab19730305@126.com

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Abstract

Soil acidity and alkalinity (pH) has a significant impact on plant growth and development. From the process, it is mainly reflected in the impact of climate and elements in soil on plant growth, while climate mainly affects carbon, hydrogen and oxygen, which account for 96% in the atmosphere. The more important elements in the soil are nitrogen, phosphorus and potassium, and the secondary elements are calcium, magnesium, sulfur and so on. This paper selects the conventional economic plant planting land as the development of the experiment, obtains the main components in the soil, and carries out the intervention experiment of different concentrations of soil pH value. The pH value in the soil is divided into four levels: pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5), pH 4 (7.5 - 8.4) as the independent variable, and takes the elements in the soil as the dependent variable for linear regression analysis. The results show that pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5), pH 4 (7.5 - 8.4) can explain the change of elements in soil. The results show that pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5), pH 4 (7.5 - 8.4) can explain the change of elements in soil. Among them, pH 1 (<5.5) and pH 4 (7.5 - 8.4) are the most unstable, while pH 2 (5.5 - 6.5) and pH 3 (6.5 - 7.5) have little impact on plant growth and are relatively stable. Therefore, the acidity and alkalinity of soil has a certain impact on the elements in soil, but it is not a decisive impact. It can be proved that the influence relationship between independent variables and dependent variables.

Keywords

Soil, pH Value, Plant, Growth and Development, Research

1. Introduction

There is very little research on the effect of soil acidity and alkalinity on plant growth in China. There are 3 academic papers from CNKI from 2007 to 2020, however, they mainly focus on the mechanism and application analysis of the impact of soil acidity and alkalinity on plant growth, belonging to review papers, and the current soil is affected by human activities, the soil pH has undergone great changes, and nutrients such as nitrogen, phosphorus, and potassium, which are indispensable for plant growth, and are all in the soil [1]. It plays an important role in the growth process, and the acidity and alkalinity in plants, pH, is an important factor causing slow plant growth and disease. From this point of view, this paper tests the important role of soil components through literature review and investigation. Scientific and reasonable methods to determine the main element model in economic plant soil are of great significance for affecting plant growth [1]. In this paper, the numbers of heavy metal elements in plant soil: No. 1 Fe (iron), No. 2 P (phosphorus), No. 3 Co (cobalt), No. 4 N (nitrogen), No. 5 Cu (copper), No. 6 Ca (calcium), No. 7 Mn (manganese), No. 8 Mg (magnesium), No. 9 B (boron) and No. 10 S (sulfur) were established by using statistical theory and method. This paper used SPSS26.0 software to fully analyze and process the data, established the model by using the linear regression analysis method, made a detailed analysis and research on the overall elements of soil pH value affecting plant growth, then evaluated the soil element model of economic plants, and gave reasonable optimization suggestions from potential impact evaluation. The effects of soil elements on economic plants as a whole were analyzed in detail, and suggestions on impact control and optimization were put forward.

In recent years, the impact of the change of soil pH value on soil elements of economic plants has become a serious problem. Through the analysis of the impact degree of soil elements, it is necessary to establish a set of element-based model to comprehensively evaluate the impact degree and the weight of different elements. This paper comprehensively uses the soil quality evaluation method as the source of data score, establishes the model through linear regression and carries out analysis and discussion [2].

2. Existing Problems and Data Sources

With the continuous change of soil pH value and the increasingly prominent impact of human activities and environmental pollution on soil and environmental quality, the environmental problems caused by the change of soil pH value have attracted more and more attention. We investigated the soil environment of an economic plant, divided the collected and tested areas into grid areas with an interval of about 0.5 km, numbered 0 - 20 cm soil according to 0.5 sampling points per square kilometer, and recorded the location of the sampling points with GPS satellite recorder. The collected soil was analyzed by special instruments to obtain the data of various soil elements contained in each sample.

This paper referred to the collection of literature data related to pH value on plant growth and development in recent years as the reference of this experiment and the pH environmental baseline of economic plants at home and abroad. The potential plant impact growth evaluation established by the soil treatment evaluation method [1] [2] widely used in China is an effective method to evaluate the impact of pH value on plant growth based on the principles of culture test method and field biological test method [3]. Based on the field collection, testing and analysis of economic plant soil samples, the environmental characteristics of No. 1 Fe (iron), No. 2 P (phosphorus), No. 3 Co (cobalt), No. 4 N (nitrogen), No. 5 Cu (copper), No. 6 Ca (calcium), No. 7 Mn (manganese), No. 8 Mg (magnesium), No. 9 B (boron) and No. 10 S (sulfur) in economic plant soil in this area were studied. Combined with the reference values, the influence coefficients of 10 soil elements were calculated:

Fe (iron) = 10, P (phosphorus) = 25, Co (cobalt) = 9, N (nitrogen) = 30, Cu (copper) = 11, Ca (calcium) = 20, Mn (manganese) = 15, Mg (magnesium) = 18, B (boron) = 9, S (sulfur) = 10

Referring to the relationship table between plant growth and development element indexes and classification of culture test method and field biological test method (see **Figure 1**), this paper established the factors affecting plant growth of 10 kinds of soil elements by linear analysis method, and formed the model of basic economic plant soil pH value affecting plant growth. According to the geochemical baseline of mine environment and the harm degree of heavy metals in each urban area, the relationship between the intensity of heavy metal pollution in soil of economic plants was divided into five levels, the model and evaluation were established, and the suggestions on pollution control and treatment were put forward.

3. Basic Hypothesis

Hypothesis 1: The data of sampling points fully reflect the basic situation of the impact of soil pH value of economic plants on soil elements.

Hypothesis 2: Data sources are true and reliable, with statistical significance.

Hypothesis 3: Ignore the influence of abnormal state on pH concentration.

4. Linear Regression Analysis

The regression analysis of this experiment was used to study the influence relationship between X (soil acidity and alkalinity) and Y (soil elements), whether

	A	B	C	D	E
1	Elements in soil	PH 1(<5.5)	PH 2(5.5~6.5)	PH 3(6.5~7.5)	PH 4(7.5~8.4)
2	3	15	28	32	22
3	8	40	58	74	56
4	4	46	25	64	23
5	7	42	21	63	22
6	10	20	23	65	22
7	2	14	18	44	22
8	6	12	25	34	23
9	5	13	21	26	13
10	1	12	23	25	22
11	9	10	11	12	14

Figure 1. Data sample.

there is an influence relationship, and how about the influence direction and degree. The following procedures were required:

First, by analyzing the basic situation of model fitting, that is, by analyzing the fitting situation of the model through the R-square value, and by analyzing the VIF value, we can judge whether there is a collinearity problem in the model and get the model formula;

Second: analyze the significance of the impact of X. If it is significant (P value less than 0.05 or 0.01), it shows that X has an influence on Y, and this study is of significance, or then analyze the direction of the influence relationship in detail;

Third: combined with the value of regression coefficient B, compare and analyze the influence degree of X on Y;

Fourth: summarize the analysis.

4.1. Results of Linear Regression Analysis

We can see from Table 1 that taking pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5), pH 4 (7.5 - 8.4) as independent variables and elements in soil as dependent variables for linear regression analysis, It can be seen from Table 1 that, the model formula was elements in soil = 3.722 − 0.035 * pH 1 (<5.5) − 0.093 * pH 2 (5.5 - 6.5) + 0.062 * pH 3 (6.5 - 7.5) + 0.091 * pH 4 (7.5 - 8.4). The R-square value of the model was 0.914, which means that pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5) and pH 4 (7.5 - 8.4) can explain 91.4% of the changes of elements in soil. During the F-test of the model, it was found that the model did not pass the F-test (F = 8.361, P = 0.040 < 0.05), that is, pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5) and pH 4 (7.5 - 8.4) will have an impact on the elements in the soil. Therefore, the impact relationship between independent variables and dependent variables can be analyzed in detail. The analysis is over (see Table 2).

4.2. Model Diagram

Model diagrams created by analysis (Figure 2).

4.3. Model Result Diagram

The model results are obtained through model analysis (see Figure 3).

Table 1. Results of linear regression analysis (n = 10).

	Non-standardized coefficient		Standardized Coefficient	t	p	VIF	R^2	Adjust R^2	F
	B	Standard error	Beta						
Constant	3.722	3.203	-	1.162	0.298	-			
pH 1 (<5.5)	−0.035	0.162	−0.165	−0.216	0.838	3.295			
pH 2 (5.5 - 6.5)	−0.093	0.351	−0.382	−0.266	0.801	11.616	0.914	−0.595	F(4, 5) = 8.361, p = 0.040
pH 3 (6.5 - 7.5)	0.062	0.122	0.436	0.512	0.630	4.096			
pH 4 (7.5 - 8.4)	0.091	0.385	0.359	0.238	0.822	12.852			

Dependent variable: elements in soil; D-W value: 2.774; p < 0.05 ** p < 0.01.

Table 2. Results of linear regression analysis—simplified format.

	Regression coefficient	95% CI	VIF
Constant	3.722 (1.162)	−2.556 - 10.000	-
pH 1 (<5.5)	−0.035 (−0.216)	−0.352 - 0.282	3.295
pH 2 (5.5 - 6.5)	−0.093 (−0.266)	−0.780 - 0.594	11.616
pH 3 (6.5 - 7.5)	0.062 (0.512)	−0.176 - 0.300	4.096
pH 4 (7.5 - 8.4)	0.091 (0.238)	−0.663 - 0.846	12.852
Sample capacity	10		
R^2	0.914		
Adjust R^2	0.804		
F value	$F(4, 5) = 8.361, p = 0.040$		

Dependent variable: elements in soil; D-W value: 2.774; $p < 0.05$ **$p < 0.01$. In parentheses is the t value.

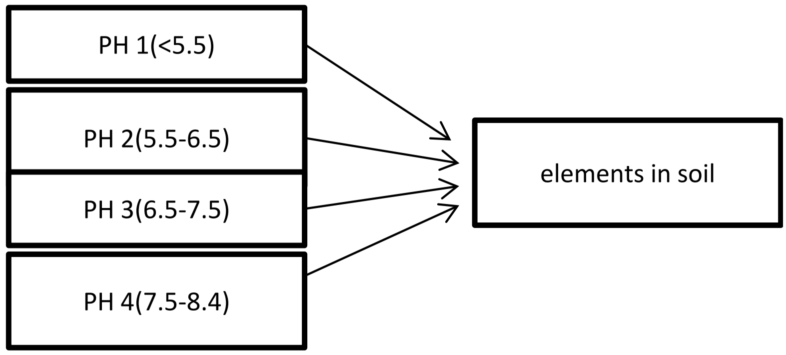

Figure 2. Model diagram.

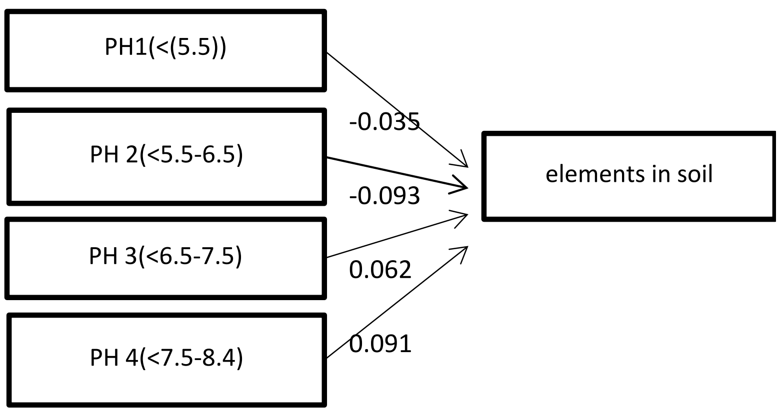

Figure 3. Model results plot.

Regression analysis is used to study the influence relationship between X (soil pH value) and Y (soil element), whether there is an influence relationship, and how about the influence direction and degree;

First: analyze the fitting of the model with the R-square value of the model.

For example, 0.5 means that the fitting degree of the model is 50%;

Second: adjust the R-square value to punish arbitrarily placing too many X, which is usually less used.

It can be seen from **Table 3** that taking pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5) and pH 4 (7.5 - 8.4) as independent variables and elements in soil as dependent variables for linear regression analysis, It can be seen from **Table 3** that the R-square value of the model is 0.914, which means that pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5) and pH 4 (7.5 - 8.4) can explain 91.4% of the changes of elements in soil (see **Table 4**).

The F-test shows that the regression model is meaningful;

First, the model passed the F test ($P < 0.05$), indicating that the model is meaningful, and at least one X will affect Y;

Second: the model did not pass the F test ($P > 0.05$), indicating that the model construction is meaningful, and X will not affect Y.

During the F-test of the model, it was found that the model passed the F-test ($F = 8.316$, $P = 0.040 < 0.05$), which means that pH 1 (<5.5), pH 2 (5.5 - 6.5), pH 3 (6.5 - 7.5) and pH 4 (7.5 - 8.4) will have an impact on the elements in the soil, so the impact relationship between independent variables and dependent variables can be analyzed in detail (see **Table 5**, **Figure 4**).

Table 3. Model summary (Intermediate Process).

R	R^2	Adjust R^2	Model error RMSE	DW value	AIC value	BIC value
0.838	0.914	0.804	2.704	2.774	58.271	59.784

Table 4. ANOVA table (Intermediate Process).

	Sum of squares	df	Mean square	F	P value
Regression	9.401	4	2.350	8.3161	0.040
Residual error	73.099	5	14.620		
Total	82.500	9			

Table 5. Regression coefficient (Intermediate Process) (n = 10).

	Non-standardized coefficient		Standardized coefficient	t	p	95% CI	VIF
	B	Standard error	Beta				
Constant	3.722	3.203	-	1.162	0.048	−2.556 - 10.000	-
pH 1 (<5.5)	−0.035	0.162	−0.165	−0.216	0.038	−0.352 - 0.282	3.295
pH 2 (5.5 - 6.5)	−0.093	0.351	−0.382	−0.266	0.051	−0.780 - 0.594	11.616
pH 3 (6.5 - 7.5)	0.062	0.122	0.436	0.512	0.030	−0.176 - 0.300	4.096
pH 4 (7.5 - 8.4)	0.091	0.385	0.359	0.238	0.022	−0.663 - 0.846	12.852

Dependent variable: elements in soil; $p < 0.05$ $^{**}p < 0.01$.

4.4. CoefPlot

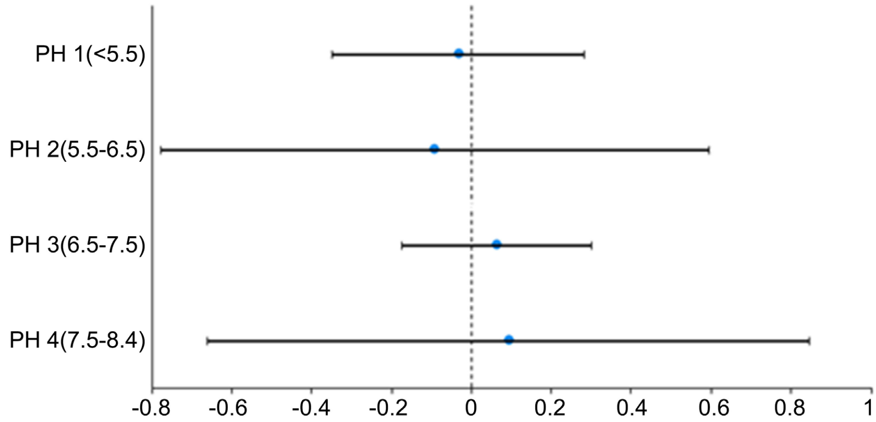

Figure 4. Regression coefficient 95% CI.

5. Evaluation of the Impact Model of pH Value in Soil on Economic Plant Growth

5.1. Evaluation

It can be seen from the results of the baseline model of heavy metal pollution in the soil of economic plants that although the proportion of each element in the soil is different, they all have different degrees of impact on the soil elements of economic plants. From the perspective of four different concentration distributions, the larger the number of stages, the smaller the impact on plant growth is more important. It can be seen that the pH values of 1 and 4 have the greatest impact on plants. At the same time, among the 10 elements of No. 1 Fe (iron), No. P (phosphorus), No. 3 Co (cobalt), No. 4 N (nitrogen), No. 5 Cu (copper), No. 6 Ca (calcium), No. 7 Mn (manganese), No. 8 Mg (magnesium), No. 9 B (boron) and No. 10 S (sulfur), the influence weight of P (phosphorus), N (nitrogen), Mg (magnesium) and Ca (calcium) is the highest. Obviously, these four elements play an important role in the economic plant growth soil [4].

5.2. Control Strategy of Soil pH Value of Economic Plants

The research shows that the influence of soil elements on plant growth is very important, and the elements in soil with different acidity and alkalinity will affect plant growth. Therefore, it is necessary to change the pH value to realize the positive influence of soil elements on plant growth. And the effect can be achieved in a short time. In this process, we should actively slow down the process of soil acidification and promote the sustainable development of economic plant agricultural production through rational soil element management. For example, a large amount of rotten farmyard fertilizer, peat soil, rotten leaf soil and green fertilizer can neutralize the pH, and solve the problems of soil hardening and low organic matter content. Soil acid regulating agent takes agricultural water retaining agent, natural peat or other organic matter as the main raw materials and adds effective bioactive components to regulate the acidity and alkalinity of soil [5].

5.3. Suggestions on Soil pH Affecting Plant Growth and Optimizing Soil Elements

Economic plant soil pH affects plant growth. Optimizing soil elements is an important part of agricultural production and soil optimization. In different pH, the impact of soil elements on plant growth can be seen. It is necessary to actively optimize the soil to achieve element stability. For example, the three soil elements indispensable for plant growth are nitrogen, phosphorus and potassium, which play the roles of photosynthesis, protein synthesis, cell differentiation and other important roles [6]. In recent years, due to the impact of human activities, the phenomenon of soil degradation is serious. Among them, soil acidification is an important form of soil acid-base imbalance, which seriously restricts the growth and development of economic plants [7]. Therefore, three aspects are suggested. First, it is necessary to establish a soil element monitoring system based on artificial intelligence to carry out 24-hour economic plant soil dynamic monitoring. Second, evaluate the surrounding environment of the economic plant area and control the pollutants to reduce the soil pollution in the economic plant area. Third, regularly measure the soil pH value, evaluate the soil quality, and scientifically optimize the soil quality to protect the environment in which soil elements promote the growth of economic plants.

6. Conclusion

In this paper, through the empirical research on the effect of soil pH on plant growth, it is concluded that the pH in the soil mainly has a certain impact on the elements in the soil, and different elements have different influences, while the main nutrients iron, Phosphorus, cobalt, nitrogen, etc. are all affected by soil pH, so improving soil pH is important for plant growth and development.

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

References

[1] Zhao, J. (2021) Soil Acidity and Alkalinity and Plant Growth. *Inner Mongolia Agricultural Science and Technology*, No. 6, 33-42.

[2] Xu, Z., Liu, G., Yu, J., *et al.* (2020) Experimental Study on the Effect of Simulated Acid Rain on Red Soil Structure and Its Cement. *Journal of Soil and Water Conservation*, **16**, 9-11.

[3] Yu, W., Sun, Z. and Song, Z. (2019) Causes, Harm and Comprehensive Control Technology of Soil Acidification in Solar Greenhouse. *Shandong Vegetable*, No. 4, 31.

[4] Zhao, J., Shen, X. and Li, X. (2019) Correlation Analysis between Soil pH Value and

Available Nutrients in Pear Orchard. *Northern Horticulture*, No. 11, 5-8.

[5] Chen, C., Xiao, B. and Yu, Y. (2019) Spatial Variation of Soil Organic Matter and pH Value in Tea Gardens in Southern Shaanxi and Their Correlation with Available Nutrients. *Journal of Northwest University of Agriculture and Forestry Science and Technology* (*Natural Science Edition*), **37**, 182-188.

[6] Wang, T.J., Yang, H.M., Gao, L.J., *et al.* (2015) Atmospheric Sulfur Deposition on Farmland in East China. *Pedosphere*, **15**, 120-128.

[7] Green, W.H. (1998) Econometric Analysis. China Social Sciences Press, Beijing.