International Journal of Agriculture and Animal Production
Vol: 05, No. 01, Jan-June 2025
ISSN: 2799-0907, DOI: 10.55529/ijaap.51.49.58

Research Paper

Extent of impact of chemical fertilizers on soil pH

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Article Info

Article History:
Received: 24 October 2024
Revised: 02 January 2025
Accepted: 10 January 2025
Published: 27 February 2025

Keywords:
Chemical Fertilizer
Crops Productivity
Soil pH
NPK
Urea

ABSTRACT

The objective of the present paper is to analyze the extent of the impact of the application of chemical fertilizers on the quality of soil, especially on the soil pH, in the interfluve of the Mayurakshi and the Basloi rivers in Birbhum district, West Bengal, India. The method used to conduct the study included a laboratory test of the soil samples, which was followed by a statistical analysis and interpretation. The soil samples have been collected in five different villages, namely Paikar, Tailpara, Kamakha, Dakshingram, and Md. bazaar, situated in different blocks in the district of Birbhum, where multi-cropping is practiced and different types of chemical fertilizers are used largely in agricultural operations. The result shows that long-term and continual application of chemical fertilizers, especially nitrogenous and urea fertilizers, to crop fields modifies the physical and chemical properties of the soil and decreases the level of soil pH. This makes the soil acidic. The reduction is more prominent where cultivation is practiced solely with chemical fertilizers, but very little or no such change in pH value is observed in the fields where farming is done by applying both chemical fertilizers and organic manures. To get rid of the problem, an integrated nutrient management system may be practiced to protect the soil from degradation and to maintain production.

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1. INTRODUCTION

The world population is increasing at a staggering rate. This is raising the demand for food, fodder, fuel, and fiber and diminishing the amount of arable land. To meet the situation, farmers all over the globe are forced to produce more food grains per unit of land per unit of time by cultivating the soil more

intensively. They are constrained to follow intensive agriculture by applying a larger amount of chemical fertilizers and other modern inputs. Chemical fertilizers are synthetic agro-inputs that are sprayed on crops and fields to supply readily available vital nutrients to the crops and increase yields [1]. It usually contains secondary and micronutrients like calcium, magnesium, sulfur, and others, along with crucial nutrients like potassium, phosphorus, and nitrogen, which are essential for the growth and development of plants.

Modern mechanized farming systems with large amounts of fertilizers and pesticides have no doubt increased the productivity of crops, but they also contaminate the environment [2]. Continuous and overuse of chemical fertilizer, especially NPK, is fraught with danger because a considerable amount of the same is lost to the soil system [3].

The physical, chemical, and microbial characteristics of soil are changed by regular application of chemical fertilizers [4], [5], [6], [3], [7]. Constant use of some fertilizers, especially those that contain ammonium-based nitrogen sources like ammonium nitrate or ammonium sulfate, can cause the soil to become acidic [8], although soil acidity is the combined result of several interrelated biogeochemical processes in the soil-plant system.

Through the nitrification process, soil bacteria use these fertilizers to change ammonia into nitrate (NO_3^-). The emission of hydrogen ions (H^+) as a consequence of this process ($2O_2 + NH_4^+ \rightarrow NO_3^+ + 2H_2O + 2H^+$) causes soil acidification [8]. Sulfur-containing fertilizers, like elemental sulfur or ammonium sulfate, can directly cause soil acidity when they break down and produce sulfuric acid ($S \rightarrow H_2SO_4 + 2H^+ + 2O_2 + 2H_2O$). Through microbial action, bicarbonate ions (HCO_3^+) and ammonium ions (NH_4^+) are released from the used urea. Subsequently, the ammonium ions go through a biological process called nitrification, in which soil microorganisms transform the ammonium ions into nitrite (NO_2^-) and subsequently nitrate (NO_3^-), which releases hydrogen ions (H^+) into the soil. All these processes of acidification, which release hydrogen ions, lower the pH of the soil [8].

Soil p^H, which is a measurement of the alkalinity or acidity of the soil, is considered a master variable in the soil because it controls a number of processes and properties of the soil. It leads to several issues, like soil degradation, soil compaction, and loss of soil carbon, and decreases its efficiency on crop yields [9], [10], [11]. Depending on the initial pH of the soil as well as the direction and rate of pH change, changes in soil pH can be beneficial or detrimental to crop production.

For instance, decreases in soil pH in alkaline soils can be beneficial because they increase the availability of phosphorous and micronutrients like zinc. However, in acidic soils, pH declines may be harmful because they enhance crop sensitivity to toxicity caused by increased solubility of manganese or aluminum as soil pH drops [8]. The drop in soil pH adversely affected microbial diversity, soil structure, and nutrient availability. Microbial populations can be upset by acidic or alkaline soils, which can have an impact on soil fertility, organic matter breakdown, and general soil health, as well as crop yields and quality.

2. RELATED WORK

A vast amount of literature has been compiled to demonstrate the relationship between the effects of chemical fertilizers and soil pH. The majority of them show that continual application of NPK, or nitrogenous fertilizers, lowers soil pH [12], [13]. Of all the major fertilizer nutrients, inorganic nitrogen is the main culprit, affecting soil pH [14]. When N-containing fertilizers are applied over an extended period of time, they cause the soil to become more acidic, which lowers the pH of the soil [15]. Belay et al. (2002), in an experiment, show that the application of inorganic N fertilizer at a lofty dose decreases the soil pH value significantly.

Mineral nitrogen causes changes in soil pH as well as numerous other soil parameters [16], [12], [17]. He added that there is a clear trend of the pH of the soil decreasing as the rate of N fertilizer application increased. Zhang et al. (2007), in his experiment, have noticed a significant decline in soil pH ranging from 0.07 to 0.12 units per year due to the application of inorganic N fertilizers for 15 years [18]. Yang X.-D. et al. (2018), in a study on the effects of long-term nitrogen application on soil acidification and solution chemistry of a tea plantation in China, show that, after 8 years, the soil pH in the tea plantation decreases from 4.16 to 2.94–3.64 in the 0–40 cm soil depth [19]. Merhaut and Darnell (1995) demonstrate a drastic

decline of soil pH (from 4.5 to 3.0) as a result of the application of ammonium nitrogen in a sand culture. In a study [20], Barak P.et al. in 1997 showed that the application of ammonium nitrate and urea at the long-term fertility trial in Arlington, Wisconsin, has caused soil acidification and a decline in soil pH values from 5.6 to 4.8 [21].

Urea fertilizer also increases the acidity of the soil because the urea is used by the plants as NH_4^+ first, and then H^+ is released into the soil, which thereby decreases the pH of the soil [8]. Belton, P.R., and Goh, K.M. (1992) found in their experiment that the soil pH value has declined up to 1.6 units in an apple orchard in New Zealand for the treatment of urea fertilizer at a rate of 50 kg/hectare/year [22].

Objectives

The main objective of the research is to examine the nature of impact of chemical fertilizer application on the soil pH value of crop fields.

3. METHODOLOGY

3.1 The Study Site

The area selected for the study is the interfluve of the Mayurakshi and the Basloi rivers in Birbhum district of West Bengal province, India. It is characterized by a wet and dry monsoon-type climate with around 170 cm of annual rainfall and a temperature of 15–35 °C. The area is basically a flat plain with clay-to-loam soils, with some lateritic patches in the west.

Farmers in this area use a variety of chemical fertilizers (NPK-based and urea-based) to produce a large number of crops, including rice, potatoes, wheat, mustard, and so on. A meager amount of organic manure, especially conventionally prepared farmyard manure, is also used by some farmers. But due to insufficient supply, it is used only on some selected plots. For data collection, five villages, namely Angargoria, Dakshingram, Kamakha, Paikar, and Tail Para, have been selected purposefully from different corners of the entire study area as shown in Figure 1.

3.2 Sample Collection

To conduct the study, two types of samples were collected from two different types of plot with almost similar environmental characteristics and similar agronomic management in the study villages in 2022.

The type-I samples have been collected in such plots where cultivation is done solely with chemical fertilizers and, somewhere, with a combination of chemical fertilizers and organic manures. Double cropping has been practiced on such plots for the last twenty years, as has the application of chemical fertilizers. The rate of application of fertilizers in such plots is around 580 kg/acre/year (NPK = 380 kg/acre and Urea = 200 kg/acre/year).

From each village, fifteen (15) samples have been collected from such plots, among which eight used only chemical fertilizers and seven used some organic manures (at 10–12 quintals per acre per year) along with chemical fertilizers for crop production. From these plots, a total of 75 (15x5) samples have been collected from five sample villages. Among them, 5x8=40 were from such plots where only chemical fertilizers are used, and the rest, 35 (5x7), were from such plots where organic manures were also used along with chemical fertilizers.

The type II samples have been collected from such a type of plot, which i**s** basically barren land. These come under cultivation occasionally and so does the application of chemical fertilizers. But all these plots are located near the selected fertilized land. From this type of plot, 75 (5 x 15) samples are collected. In this way, 75 pairs of samples comprising fertilized and non-fertilized soil are prepared.

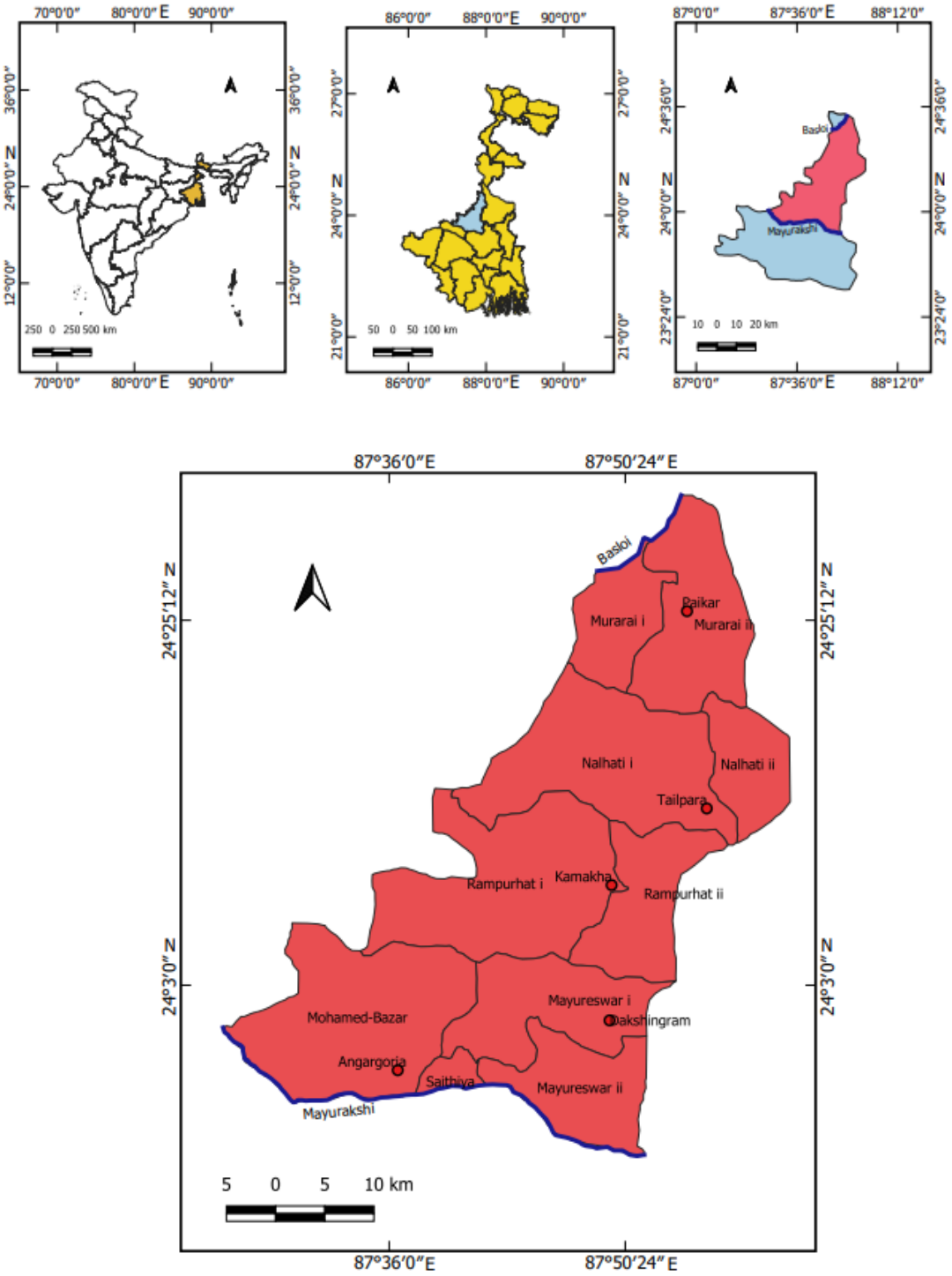


Figure 1. Location of the Sample Villages

3.3 Methods

The methodology used to conduct the study is a laboratory test of the soil samples, which was followed by a statistical analysis and interpretation. For finding out the pH value of the samples, a glass electrode p^H meter is used. Firstly, all the samples (75+75) have been prepared accordingly for the test and analyzed in the laboratory to find out the p^H value of each sample.

3.4 Analysis

To find out the impact of chemical fertilizers on soil p^H values, a comparison has been made between the p^H values of each pair (fertilized and non-fertilized) of samples. Then their difference is calculated. This difference is a decrease in soil p^H value. For determining the impact of fertilizers on soil p^H and analyzing its magnitude statistically, a student's t test has been done with (n-1) degrees of freedom.

4. RESULTS AND DISCUSSION

The results of the study given in Table 1 show a difference in soil p^H value between the samples of fertilized and non-fertilized soils, and the value of the fertilized soil sample is always lower than that of the non-fertilized soil. The difference is large and significant in the fields where cultivation is practiced solely by applying chemical fertilizers. It indicates that the decrease in soil p^H value is greater in the fields where cultivation was conducted after applying only a lofty dose of chemical fertilizers and without organic manures, but very less or zero in the fields where organic manures were used in the production process along with chemical fertilizers.

Table 1. Changes of Soil pH Values in Different Study Villages

Sample Villages	pH value of the samples			
	Cultivated with only chemical fertilizers		Cultivated with chemical fertilizers and organic manures	
	Decrease	Extent of decease (units)	Decrease	Unchanged
Angargoria	100%	0.25 - 1.42	71.4%	28.6%
Dakshingram	100%	0.51 - 1.29	100%	-
Kamakha	100%	0.80-1.22	57.1%	42.9%
Paikar	100%	0.80 to 1.21	100%	-
Tail Para	100%	0.50-1.10	71.4%	28.6%
Total/average	100%	-	79.98%	20.02%

Source: Calculated with experimented data

Several studies have shown that adding organic or inorganic fertilizers over an extended period affects the health of the soil. Most of them confirm the fact that various fertilizer treatments, particularly NPK, or nitrogenous fertilizers, lower the pH of the soil. In the present study, it has been found that the p^H value of the soil has decreased almost in all cases after the application of chemical fertilizers. From Table 1, it is evident that, the result is 100%, and the decrease in pH value is up to 1.42 units when the cultivation is practiced solely with the application of chemical fertilizers. This indicates that the application of chemical fertilizers will decrease the soil p^H value. Such a type of 40 samples collected from 40 different plots in five different villages show a significant decrease in soil pH. Among 40 such samples, more than 37.5% show a decrease in p^H value, which is more than 1 unit Table 1.

The study also illustrates that the p^H value difference is low in the samples collected from the plots where cultivation is done with the help of both chemical fertilizers and organic manures. In some cases, the difference is zero, indicating no change in pH values. Among 35 such samples, 20.02% of cases show such results as found in Table 1. But in the case of the rest of the 78.98% samples, the decrease in soil p^H value is noticed, although insignificant in amount.

As far as the village-level study is concerned, it is found that all the plots cultivating crops solely by applying chemical fertilizers at Angargoria show a decrease in p^H value of 0.25–1.42 units, but in plots where crop cultivation is practiced both with the help of chemical fertilizers and organic manures, it is nominal (0.00-0.16 units). Among the 7 such types of samples in this village, 28.6% show no change in value as shown in Figure 2.

In the case of Dakshingram village, a decrease in soil pH value is observed in all 15 pairs of samples, which ranges from 0.10 to 1.29 units. From the Figure 3, it is cleared that, five samples show a decrease of more than 1 unit. All the samples collected from the fertilized fields here show a higher level of decrease in

pH value. At Kamakha village, the soil pH value decreased from 0.00 to 1.30 units after the application of chemical fertilizers. In this village, 25% of the samples show a decline of more than 1 unit. The samples which are collected from the plots that use chemical fertilizers and organic manures show that the changes are insignificant or zero. In such types of soils, no change in pH value is observed among the 42.9% of samples as shown in Figure 4.

The study shows that, in the case of Paikar village, 100% of the samples show a decrease in soil pH value ranging from 0.00 to 1.21 units. In spite of applying organic manures, the pH level has decreased in this village Figure 5.

At Tailpara, a decrease in soil pH takes place by 0.00 to 1.10 units due to the application of chemical fertilizers in the crop fields. Here, the decrease in fertilized crop fields is significant, but the decrease is very minimal in the case of plots where organic manure is also used along with chemical fertilizers Figure 6.

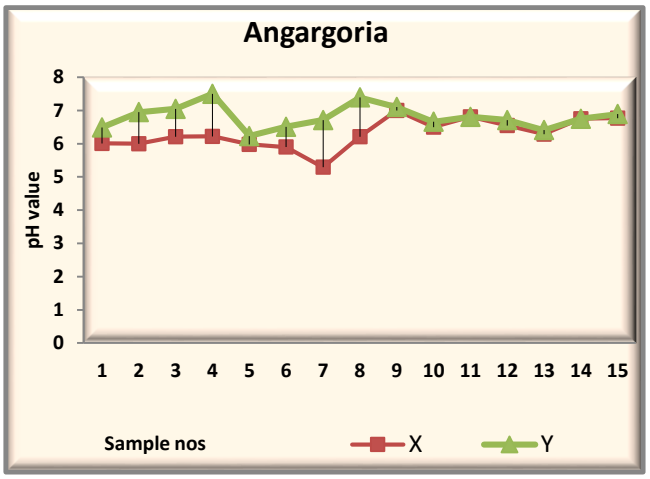


Figure 2. Angargoria Village

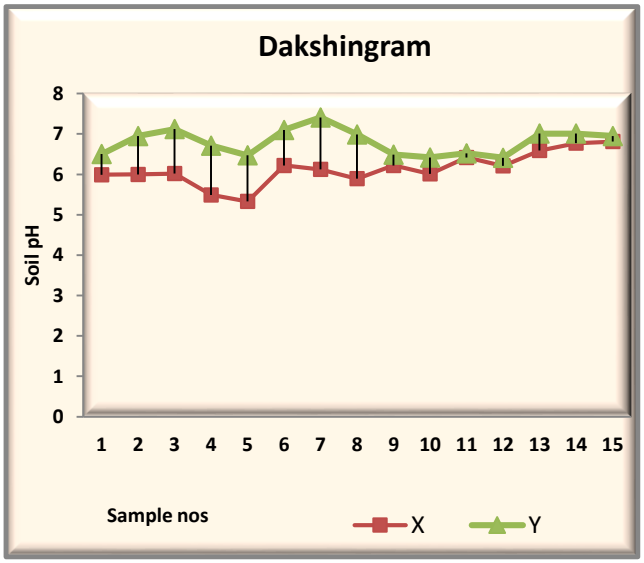


Figure 3. Dakshingram Village

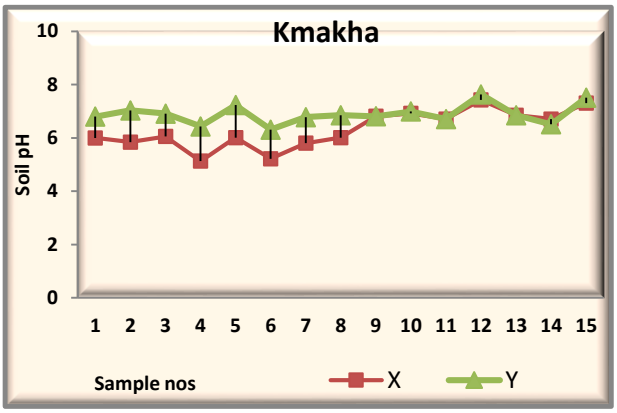


Figure 4. Kamakha Village

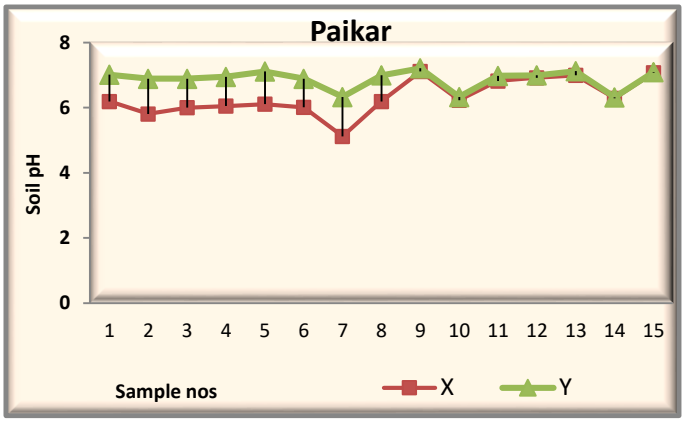


Figure 5. Paikar Village

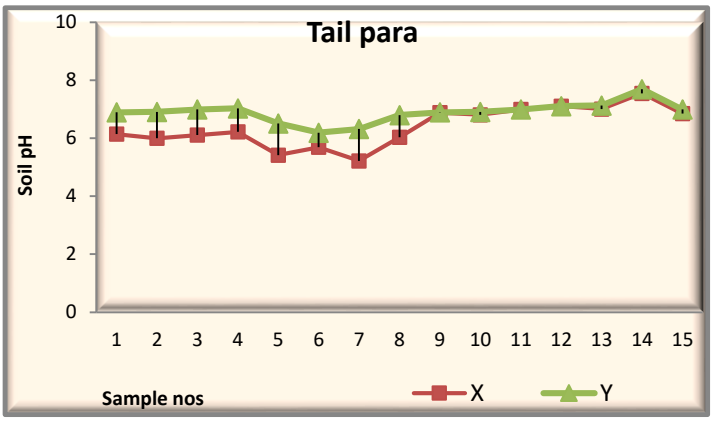


Figure 6. Tail Para Village

From Table 2, it is found that the observed value (3.92) of t at Angargoria village is greater than the tabulated value (2.98) at the 1% level of significance. So the null hypothesis (Ho: $\overline{X} = \overline{Y}$) is rejected and the alternative hypothesis (Hi: $\overline{Y} > \overline{X}$) is accepted. This indicates that the pH value of fertilized soil and non-fertilized soil is not equal, and the same is lower in the case of X samples or fertilized soil. This clearly points out the fact that the pH value of fertilized soil declines.

Table 2. Distribution of T Test Results at Different Study Villages

Sample Villages	T Test Result		
	Observed Value	Tabulated Value	Level of Significance
Dakshingram	6.09	4.14	0.1%
Kamakha	4.53	4.14	0.1%
Paikar	5.00	4.14	0.1%
Tail Para	4.45	4.14	0.1%

Source: Calculated with analysed data

In the same way, the t values for other villages have been calculated and placed in Table 2, it is found that the observed values of t at Dakshingram, Kamakha, Paikar, and Tailpara villages are 6.09, 4.53, 5.00, and 4.45, respectively, whereas the tabulated value of t in those cases is 4.14. In all the cases, the observed t values are greater than those of the tabulated values at the 0.1% level of significance. So in all the cases, the null hypothesis (Ho: $\overline{X} = \overline{Y}$) is rejected and the alternative hypothesis (Hi: $\overline{Y} > \overline{X}$) is accepted. This indicates that the pH values of fertilized and non-fertilized soils are not equal, and there is a difference in pH values between the two types of samples. The result also points out that the pH value of the fertilized soils is lower than that of the non-fertilized soils. In all the villages except Angargoria, the level of significance is very high. This strongly supports the fact that the application of chemical fertilizers to crop fields decreases soil pH values.

5. CONCLUSION

The study indicates that continuous application of chemical fertilizers, especially NPK and urea fertilizer, along with some other factors, acidifies the field soil in the Mayurakshi-Basloi interfluves, and subsequently, the pH value of that soil is lowered with time. The extent of this effect varies with the type and dosage of fertilizer and the period of time over which the fertilizer is applied. In the years to come, more food grains will be required to feed the world's expanding population. To produce more in this scenario, the farmers will need to be compelled to use more agrochemicals, especially chemical fertilizers. This will further lower the pH of the soil and degrade many aspects of the ecosystem. In order to resolve this issue, an integrated nutrient management system based on scientific fertilizer management must be implemented. Additionally, soil amendment should be carried out in order to improve the chemical and physical characteristics of the soil and lessen soil acidity. It will increase agricultural sustainability and lessen the need for chemical fertilizers and chemical leakage into the environment.

Acknowledgments

The author thanks Dr Gunin Chattpadhyay, soil scientist of ASEPAN Laboratory, Visva-Bharati, University, for helping in sample analysis.

Funding Information

This research work is not funded by any Government of Non-Government body

Author Contributions Statement

Name of Author	C	M	So	Va	Fo	I	R	D	O	E	Vi	Su	P	Fu
Dr Lakshman Chandra Pal	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

Fo : **Fo**rmal analysis E : Writing - Review &**E**diting

Conflict of Interest Statement

I, the author had full access to all in this study and take complete responsibility for the integrity of data and the accuracy of data analysis. I declare there is no conflict of Interest.

Ethical Approval

I assure that this article do not have any plagiarism

Data Availability

There is no additional dada set for the research.

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How to Cite: Dr. Lakshman Chandra Pal. (2025). Extent of impact of chemical fertilizers on soil ph. International Journal of Agriculture and Animal Production (IJAAP), 5(1), 49-58. https://doi.org/10.55529/ijaap.51.49.58

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