International Journal of Progressive Sciences and Technologies (IJPSAT)
ISSN: 2509-0119.

Vol. 32 No. 1 April 2022, pp. 411-418

Application Of The Randomized Complete Block Design To Investigate The Effect Of Soil Ph And The Amount Of Calcium In The Soil On The Rate Of Growth Of Tree Seedlings

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Abstract – Trees play a crucial role in maintaining the beautiful nature of the environment and keeping it in its natural state. They also play diverse roles to both humans and animals. For instance, a few trees are a source of income to farmers, fuel, food and protecting the soil. The rate at which forests are destroyed is alarming since day in day out trees are being cut without reforestation, reducing the forest cover, which leaves the soil bare and exposedto every agent of erosion. The aim of this study is to investigate the effect of soil pH and the amount of calcium in the soil on the rate of growth tree seedlings. Specifically, the study focused on the effect of calcium on the tree seedlings growth rate, effect of pH on seedlings growth rate and effect of the interaction between pH and calcium on the growth of seedlings. A randomized complete block design was used for data collection. Secondary data used for this study was collected from the Kenya Forest Research Institute. The data analysis was done using Excel and R statistical software. The results were in form of descriptive statistics and Analysis of variance as an inferential statistics. The results showed that calcium amount, pH and their interaction had a statistical effect on the rate of growth of the tree seedlings. The results also showed that the highest growth rates obtained at pH levels of 6 and calcium amount of 20 grams per 1m^2 plot. The study thus recommended consideration of optimal levels of calcium and pH for fast rate of growth of tree seedlings.

Keywords – Tree seedlings, calcium, pH, Randomized complete block design, Analysis of variance

I. INTRODUCTION

A statistical experiment is defined as a test or series of runs in which purposeful changes are made to the input variable of the process or system so that we may be observed in the output response (Seltman, 2012). The output of an experiment is affected by one or several factors which its effect is either mutually or independently; in real-life situations, most reactions are affected by more than one factor at different levels when several are investigated simultaneously in a single experiment, we refer to it as a factorial experiment. An experimenter is always interested in knowing how each factor affects the output response or an interaction effect between the factors being investigated (Seltman, 2018). Light is a fundamental factor limiting the growth and survival of seedlings in closed forests (Tripathi et al., 2020). Recent work has also suggested that soil pH may be of equal or greater importance than light. The influence of soil in defining species and plant community distribution is well known. Toxics ions, due to their impact on soil solubility. At low pH, the availability of essential micronutrients Fe, Ca, Zn is increased, as is the availability of phosphorus decreases (Xie et al., 2019).

Plants with optimal growth and survival below and above pH 5-7 are known as acidophiles and caliphates (Soti et al., 2015). Coffee is an essential crop in Kenya; it earns the country a lot of foreign income through exportation; calcium ions are a crucial macronutrient in coffee and are involved in several physiological stress responses. Due to the high rate of forest destruction, acid rains are more likely to invade should immediate interventions not be taken. This acid rain depletes soil base captions from

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pools, especially calcium, and limits the uptake and incorporation of calcium in trees. When the availability of calcium is low acid-induced foliar leaching may lead to aggravation of calcium deficiency (Massimi & Radocz, 2021).

Soil pH is the measure of acidity or basicity of soil. It can also be defined as the negative logarithm of the hydrogen ions concentration in the ground (McCauley et al., 2009). The pH scale runs from one to fourteen at a value of seven; the concentration of hydrogen ions is neutral (neutral pH that is neither acidic nor basic) as the pH values increase from seven basicity increases while when it decreases from seven acidity increases. Several factors cause the difference in the pH values. These include the soil parent material and amount of yearly. Rainfall an area receives. Most plants enjoy slightly acidic conditions. Pine oak, gardenia, blueberry, the azalea is among the trees that require very acidic conditions of 4.5-5.5 (Li et al., 2017). has indirect, yet far-reaching effects on plants a lower rate of growth as the plant can't manufacture enough food to support it. The other product is that it can cause plant poisoning shouldit be shallow. Maintaining the pH of soil at the right level is a continuous process, especially in natural acidic soils since rainfall, fertilizers can shift your pH and cause harm to your plants (Li et al., 2017).

Soil acidity is associated with hydrogen and aluminium in exchangeable form. Since soil acidity is a condition that results from prolonged leaching of soil soluble salts, this makes the soil in humid areas acidic (Kamran et al., 2018). Calcium plays a vital role in plant growth, specifically cell wall development, cell division and pollination. Calcium in the form of due to improper cell wall formation (Choudhary & Kharche, 2018). Since calcium is not mobile within the plant, the plant relies on transpiration in which plant roots take up soil solutions that contain Ca, transport them to the required areas of the plant that's the tips of the crop. Anything that slows transpiration, such as high humidity or cold temperatures, can induce Ca deficiencies even if Ca levels are sufficient in the growing medium (Choudhary & Kharche, 2018).

Forest coverage in Kenya has been declining over the years. Attempts to bring back the environment to its normal state seems to bear fruits though at a prolonged rate which cannot be compared with the rate forests are being destroyed. The growth of trees is affected by a number of factors, and among them is the soil pH and amount of calcium in the soil, the two elements. These factors can be put into control by farmers should test be carried out and determine what plants require and at what proportion. The research, therefore, seeks to establish and determine how soil pH and calcium affects the rate of growth of tree seedlings in the nursery bed and come up with a conclusion that will give which factor facilitates the first growth rate and also give if there is an interaction effect between the two that can increase the rate of growth.

II. METHODOLOGY

2.1. Research Design

The research design that was used for data collection in this study was a randomized completely block design. This design was convenient to this study because:

i. It was extra unique than the completely randomized design.

ii. There was no limit on the variety of treatments replicates.

iii. Some treatments could be replicated extra instances than others.

The experiment was conducted in a $100m^2$ plot, then portioned into subplots. Each subplot was then subjected to different treatment combinations.

2.2. Data collection

The data used in this study was secondary data obtained from Kenya Forest Research Institute (KEFRI). The measurement taken were the heights of the tree seedlings measured in centimeters and the values recorded. Observational method of data collection was considered since it helped to gather the data within a concise period and at a relatively cheap cost. The measurements were taken using a fifteen-centimeter ruler calibrated in centimeters with the millimeter scale. In addition, the observations are going to be recorded in one decimal place.

2.3. Variables of the Study

In this study, the dependent variable are the observations on the heights of seedlings under different conditions of calcium

amounts and soil pH. The independent variables were the soil pH values and amount of calcium in the soil and also the interaction of the two if there will be an interaction effect between the two.

The model used was of the form:

$y_{ijk}=\mu + \tau_i + \beta_j + (\tau\beta)_{ij} + \varepsilon_{ijk}$

y_{ijk} =The observation made after application of i^{th} and j^{th} treatment in k^{th} repetition

μ =Grand mean

τ_i =Effect of factor i^{th} (pH) taking the effect of the other elements to be fixed

β_j =Effect of element j^{th} (amount of calcium "blocks") taking the impact of the other elements to be fixed

$(\tau\beta)_{ij}$ =Interaction effect

ε_{ijk} =Random error ($\varepsilon_{ijk} \sim N(0, \sigma^2)$)

2.4. Data Analysis

The data was analyzed using R software. The results of the analyzed data were presented in form of ANOVA tables and conclusions made on the significance of the soil pH and amount of calcium on the growth of tree seedlings.

III. Results and Discussions

3.1 Data Presentation

The data collected from several seedlings from the experiment is presented in Table 1. The values in the table represent the height (cm) of seedlings recorded after a period of three weeks. The row values represents the height (cm) of seedlings for different pH levels, while the column values is a representation of the height (cm) of seedlings for different amounts of calcium that were applied in the field.

Table 1: Tabular presentation of the experimental data

	Calcium levels		
pH Levels	10	20	30
4	5.2,5.4,6.3	7.4,7,7.6	6.3,6.7,6.1
5	7.1,7.4,7.5	7.4,7.3,7.1	7.3,7.5,7.2
6	7.6,7.2,7.4	7.6,7.5,7.8	7.2,7.5,7
7	7.2,7.5,7.2	7.4,7,6.9	6,6.6,6.4

3.2 Descriptive Statistics

The grand mean for the height of the seedlings was 7.036111 cm. The averages for the seedling heights across the different pH levels is presented in Table 2. A pH level of 6.0 produced the highest height of the tree seedlings (Table 2). The averages for the seedling heights across the different amounts of calcium is presented in Table 3. The level of calcium of 20g produced the highest average length of the tree seedlings (Table 3). The averages for the seedling heights across the different combinations of pH levels and calcium amounts is presented in Table 4. The combination of a pH level of 6.0 and a calcium level of 20 produced the highest length of the tree seedlings (Table 4).

Table 2: Average seedlings lengths for different levels of pH

pH levels	4	5	6	7
Average height (cm)	6.834	7.103	7.403	7.238

Table 2: Average seedlings lengths for different levels of Calcium

Calcium levels	10	20	30
Average height	7.107	7.383	6.965

Table 4: Average seedlings lengths for different combination levels of pH and Calcium

	Calcium		
pH	10	20	30
4	6.548	6.834	7.121
5	6.921	6.969	7.017
6	7.293	7.303	6.913
7	7.066	7.238	6.809

The results in Figure 1 shows that the seedlings between pH values five and six have the highest average seedlings heights. The pH values of four and below and pH values greater than seven yielded lower heights of the seedling heights. This may be due to the fact that at both values there are have strong acidic and basic conditions, which may not be optimal pH to facilitate the fast growth of seedlings.

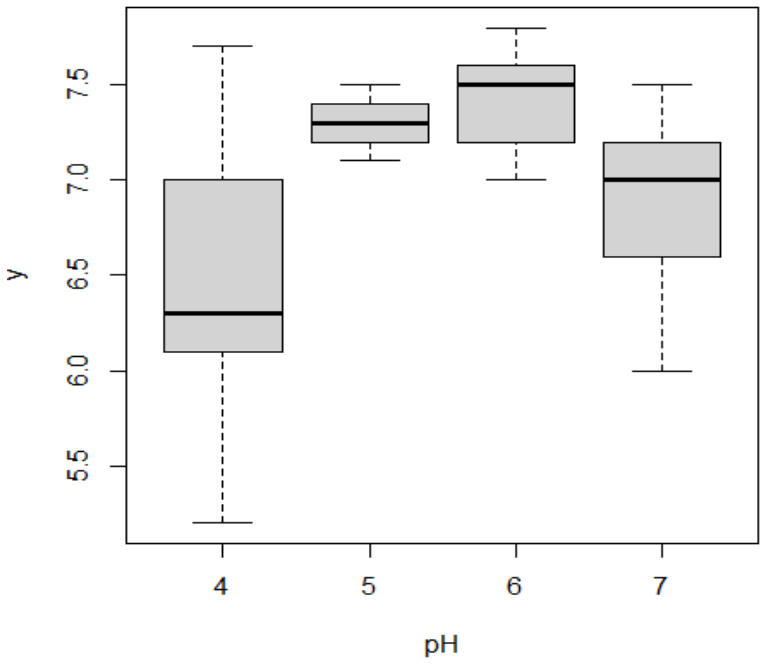

Figure 1: Box plot of soil average seedling heights against the soil pH levels

Figure 2 shows that the rate of growth is highest when the amount applied is 20g. Additionally, the figure shows that that growth increases as the amount of calcium in the soil increases up to a certain amount for this case (20g) and starts to decrease when the amount exceeds the optimal amount.

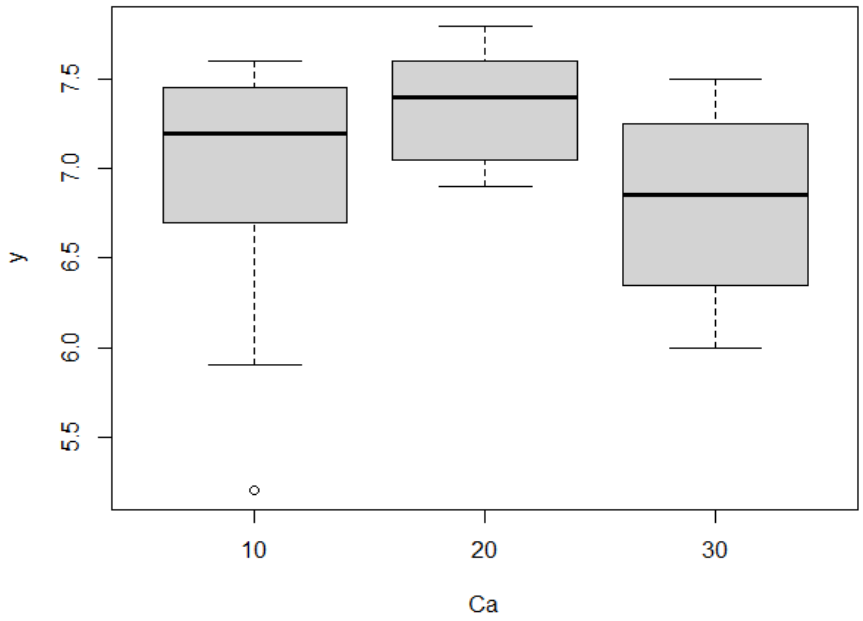

Figure 2: Box plot of soil average seedling heights against the calcium levels

Figure 3 shows the interaction of different amounts of calcium fertilizer at different soil pH values. The results shows how the heights of the seedlings vary with changes in the level of calcium amounts and the pH values. The seedlings thrive very well at around pH values six and calcium amounts 20g. At the extremes, when the pH value is low (4), and the calcium amount is low (10), the rate of growth is very slow. It can also be observed at the rare end where the amounts of fertilizer and pH are relatively high, the rate of growth slows down.

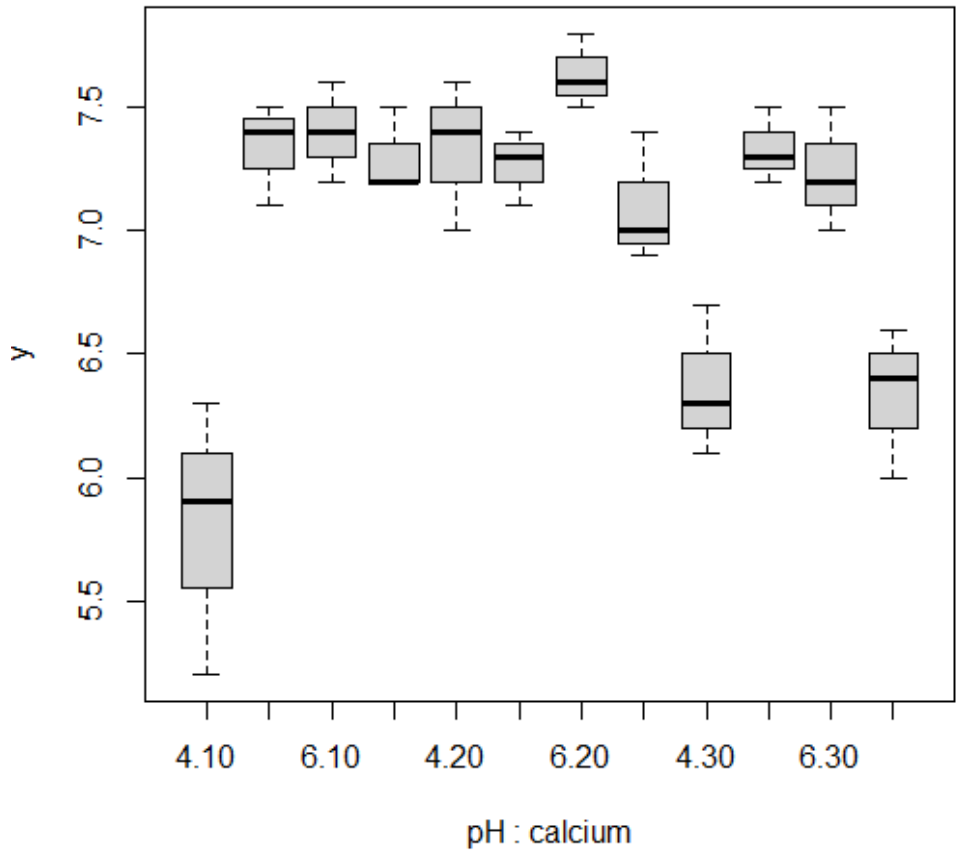

Figure 3: Box plot of soil average seedling heights against the different combination of pH and calcium levels

3.3 Analysis of Variance for Effect of Soil pH and Calcium on Growth Rate of Seedlings

On analysis of the effect of calcium on the growth rate of seedlings, the following hypothesis was

Tested;

H_0: $\tau_1 = \tau_2 = \tau_3 = 0$ (calcium has no significant effect on the rate of growth of tree seedlings)

H_1: Calcium has a significant effect on the rate of growth of tree seedlings

From the ANOVA in table 5, the p-value (0.0254) is less than the level of significance (0.05). Therefore, null hypothesis is rejected at a 5% level of significance. The conclusion is that the effect of calcium is statistically significant effect at 5% level of significance.

Table 5: Analysis of variance for effect of soil pH and calcium on seedlings growth rate

	Df	Sum of Sq	Mean Sq	F value	Pr(>F)
pH	1	0.813	0.8134	2.785	0.0049
Calcium	1	0.12	0.1204	0.412	0.0254
pH:Calcium	1	1.704	1.7041	5.835	0.0216
Resiudals	32	9.345	0.292		

On the testing of the soil pH, the following hypothesis was tested;

H_0: $\beta_1 = \beta_2 = \beta_3 = \beta_4$ (Soil pH has no significant effect on the rate of growth of tree seedlings)

H_1: H_0 is not true (Soil pH has a significant effect on the rate of growth of tree seedlings)

From the ANOVA table, the p-value (0.0049) for soil pH is less than our 0.05 (level of significance). The null hypothesis is rejected at a 5% level of confidence. The effect of soil pH is thus statistically significant.

To test the effect of the interaction between soil pH and calcium levels, the following hypothesis was tested.

H_0: $\tau\beta_{ij}$=0 (there is no interaction effect between calcium and soil pH on the rate of growth of tree seedlings)

H_1: $\tau\beta_{ij} \neq 0$ (there is interaction effect between calcium and soil pH on the rate of growth of tree seedlings)

The null hypothesis is rejected at a 5% significant level and conclusion is made that the interaction between soil pH and the amount of calcium is statistically significant since the probability value (0.0216) is less than the 5% level significance.

The results have thus shown that Calcium (Ca) is one of the secondary plant nutrients that is essential for plant growth even though this elements are required in more negligible amounts compared to macronutrients. Calcium is part of every plant cell, it keeps cell walls upright and increases fruit set and quality (Olmedo et al., 2021). The pH of the soil plays a major role in how well the plants can absorb the nutrients provided them. The wrong pH often won't kill plants outright, but it can affect their growth and result in subpar blooms or crops, depending on how sensitive the plant is (Bhaskar et al., 2021). As seen in this study, for tree seedlings, the optimum pH range is from 5.5 to 7.0.

IV. Conclusion

In conclusion, the study revealed that it is evident from the results that the effect of the amount of calcium has a statistically significant effect on the rate of growth of tree seedlings. On the other hand, the effect of soil pH is also significant to the rate of growth of the seedlings. The interaction effect between soil pH and the amount of calcium in the soil on the rate of growth of tree seedlings also statistically significant. Therefore, optimal levels of soil pH and calcium amounts need to be put into consideration as far as the rate of growth of tree seedlings is concerned.

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