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Soil pH Management through Conservation Tillage: Impact of Methods, Depth, and Timing on Agricultural Soil Dynamics

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Abstract: Soil pH is a critical factor influencing soil fertility, plant growth, and ecosystem health. Conservation tillage, characterized by reduced soil disturbance and preservation of soil structures, has been widely adopted as a sustainable agricultural practice. However, its impact on soil pH is not yet fully understood. This study evaluates the effects of various tillage methods, operational depths, and periods on soil pH using tractor-operated tillage systems. Field experiments were conducted at Lagos State University of Science and Technology, Ikorodu, Lagos, Nigeria, using four tractor models. The tillage operations included ploughing (first and second), harrowing, and ridging, performed at three various depths (10 cm, 15 cm, and 20 cm) and analyzed during different periods (before, during, and after operations).Soil samples were collected and analyzed for pH through laboratory physiochemical tests. Results revealed that the highest pH value (7.01) was recorded before harrowing at a depth of 20 cm, while the lowest pH value (4.03) occurred during the second ploughing operation at 15 cm depth. Significant differences in soil pH were observed across operations and depths, indicating the influence of tillage practices on soil chemical properties. Conservation tillage methods and shallow operational depths were associated with higher soil pH, where as deep tillage and prolonged operation periods contributed to soil acidification. These findings emphasize the importance of tailored tillage practices to optimize soil conditions, enhance soil health, and support sustainable agricultural productivity. The study provides valuable insights for farmers and agricultural practitioners, promoting effective soil pH management through conservation tillage strategies.

Keywords*: Soil pH, Conservation Tillage, Soil Health, Sustainable Agriculture, Agricultural Productivity*.

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I. INTRODUCTION

Soil pH is a fundamental aspect of soil chemistry that affects nutrient availability, microbial activity, soil fertility, plant growth, and ecosystem health (Sadiq *et al.*, 2021; Celik *et al.*, 2021; Lv *et al.*, 2023, Brady & Weil, 2008).It plays a crucial role in determining the effectiveness of fertilizers and the suitability of soils for different crops. Maintaining optimal soil pH is essential for maximizing crop productivity and ensuring sustainable agricultural practices (Ozbolat *et al.*, 2023; Li *et al.*, 2021). One of the key factors influencing soil pH is the method and intensity of soil tillage, which is been widely adopted as soil disturbance that can significantly impact on soil structure, organic matter, microbial communities, and mitigate climate change (Hobbs et al., 2008). However, the effects of different tillage methods on soil pH are not fully understood, particularly concerning the depth of tillage operations and the duration of tillage activity ((Bankole *et al.*, 2022; Frontiers, 2023).

Traditional tillage practices often involve deep soil disturbance, which can alter soil pH by mixing surface and subsurface soil layers, affecting the distribution of soil amendments and natural soil acidity or alkalinity. Conservation tillage methods focus on reducing soil disruption, which may lead to more stable soil pH levels over time. The depth of tillage operations and the time spent on land preparation can also impact soil pH by influencing soil aeration, organic matter decomposition, and microbial activity(Hou *et al.*, 2022; Shin *et al.*, 2019).

Tillage methods, including conventional tillage, reduced tillage, and no-till, can impact soil pH in various ways. Conventional tillage involves deep soil disturbance, which can mix soil layers and affect the distribution of soil

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amendments, potentially altering soil pH. Studies have shown that conventional tillage can lead to more variable soil pH due to increased soil erosion and runoff (Lal, 2004). A study by Shrestha *et al.* (2013) found that conventional tillage often results in increased soil acidity in the surface layers due to enhanced organic matter decomposition and nutrient leaching.

Recent studies have highlighted the impact of conservation tillage on soil health, with practices such as no-tillage and straw retention showing a stabilizing effect on soil pH and microbial communities (Hou *et al.*, 2022; Shin *et al.*, 2019). These practices minimize soil disturbance, reduce organic matter decomposition, and promote the formation of stable soil aggregates, which are less prone to pH fluctuations (Zhang et al., 2018; Frontiers, 2023). Conversely, intensive tillage can exacerbate pH variability by accelerating organic matter breakdown and altering microbial activity in deeper soil layers (Freedman & Zak, 2015). This study aims to expand on existing research by analyzing the effects of different tillage practices and operational depths on soil pH. The findings are intended to provide actionable insights into optimizing tillage strategies for sustainable agriculture, particularly in regions facing challenges with soil fertility and acidity management. Soil pH is a pivotal determinant of soil quality, directly influencing nutrient solubility, microbial diversity, and overall crop productivity (Bello et al., 2020). Understanding the interplay between tillage practices and soil pH is critical for developing sustainable agricultural systems(Bankole *et al*. 2022). Tillage operations, which involve mechanical manipulation of soil, impact its physiochemical properties by modifying soil structure, aeration, and organic matter content. These changes can lead to variations in soil pH, especially under different depths and intensities of tillage (Zhang et al., 2018; Frontiers, 2023).

Conservation tillage, such as no-tillage and straw retention, has gained attention for its ability to stabilize soil pH and enhance microbial diversity. These practices preserve soil organic matter and maintain soil aggregates, mitigating pH fluctuations and promoting sustainable farming systems (Li *et al.*, 2021; Frontiers, 2023). In contrast, conventional and deep tillage methods can disturb soil layers, accelerating organic matter decomposition and influencing nutrient dynamics, often resulting in greater pH variability (Freedman & Zak, 2015; Panettieri et al., 2015).

Recent studies have also explored the interaction of tillage with external factors, such as biochar application and fertilization. These combinations have been shown to improve soil nutrient content, pH stability, and crop yield. For instance, biochar-enhanced tillage practices have demonstrated the potential to raise pH levels in acidic soils while improving the availability of key nutrients like phosphorus and potassium, particularly in deeper soil layers (Frontiers, 2023).

Despite these advancements, the role of tillage depth remains underexplored in many agro-ecological contexts, particularly in tropical regions. Deeper tillage often leads to soil compaction and nutrient leaching, while shallow tillage may limit root penetration and nutrient uptake. This study aims to evaluate the specific effects of tillage practices, operational depths, and timing on soil pH under different farming conditions. By bridging this knowledge gap, we aim to provide actionable insights to guide farmers and policymakers in adopting soil management practices that enhance soil health, boost productivity, and promote sustainability (Bello *et al.*, 2022).

While substantial research has explored the effects of tillage methods and depth on soil pH, there is limited information on the combined impact of these factors and the duration of tillage operations. Most studies have focused on individual aspects of tillage or have examined soil pH changes in isolation, without considering the interplay between tillage methods and depth (Blanco-Canqui & Ruis, 2018). There is a need for integrated studies that examine how these factors collectively influence soil pH to provide a more comprehensive understanding of soil management practices.

II. MATERIALS AND METHODS

- *Site Description and Design of Experiment*

The study was conducted in Lagos State University of Science and Technology, Ikorodu, west central State of Nigeria under the western vegetation in sandy-loamy soil. The current study area falls within geographical location $16^{0}37'0''$ North, $3^{0}37'0''$ east on the western part of Nigeria.. The two models of tractors used for the tillage operations were New Holland and Massey Fergusson. In order to achieve experimental results, the following variables were combined. The variables are Tractor model, Tillage Operations(first plough, second plough, harrowing and rigging) and depth of operations (10, 15 and 20cm). These variables were carefully combined for the different runs of the tractor.

This field experiment was conducted on a carefully measured 400 meters by 360 meters mapped 14.4 hectares of land and later divided into 50 by 10 meters per each experimental plots.

On each of the experimental plots the soil samples of each site of operations were collected before, during and after the four different tillage operations (1^{st} plough, 2^{nd} plough, harrowing and ridging) have been performed in various combination. The soil samples for every similar operations by the tractors are collected as composite and laboratory analysis were carried out on each of the composites soil samples to determine the state of the soil. Physiochemical tests was carried out to analysed for soil PH in each of the soil samples.

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III. RESULTS AND DISCUSSION

At the end of the field operation, the data collected were as presented in the tables and figures below.

Table1: Tillage operations with depth of cut on soil PH

Depth of cut	first Plough	Second plough	Harrowing	Ridging
10cm	6.06	6.21	5.82	6.54
15cm	5.89	5.96	5.89	6.53
20cm	6.05	5.79	5.55	6.47

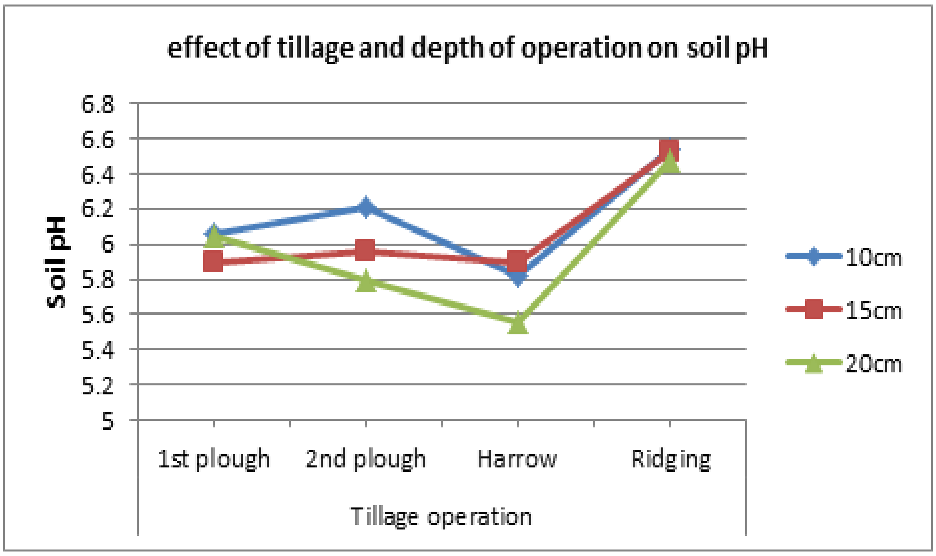

Fig. 1 Effect of Tillage and Depth of Operation on Soil pH Considering Depth

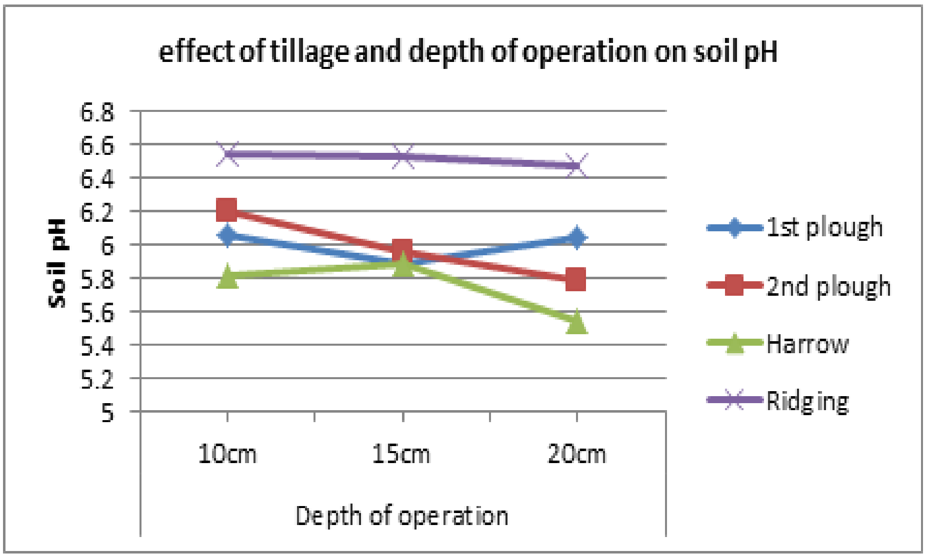

Fig. 2 Effect of Tillage and Depth of Operation Considering Farm Operation

Table 2 Tillage and Period of Operation on Soil PH

Period of operation	first Plough	Second plough	Harrowing	Ridging
Before	5.86	6.1	5.8	6.41
After	6.13	5.88	5.18	6.45
During	6.01	5.98	6.28	6.68

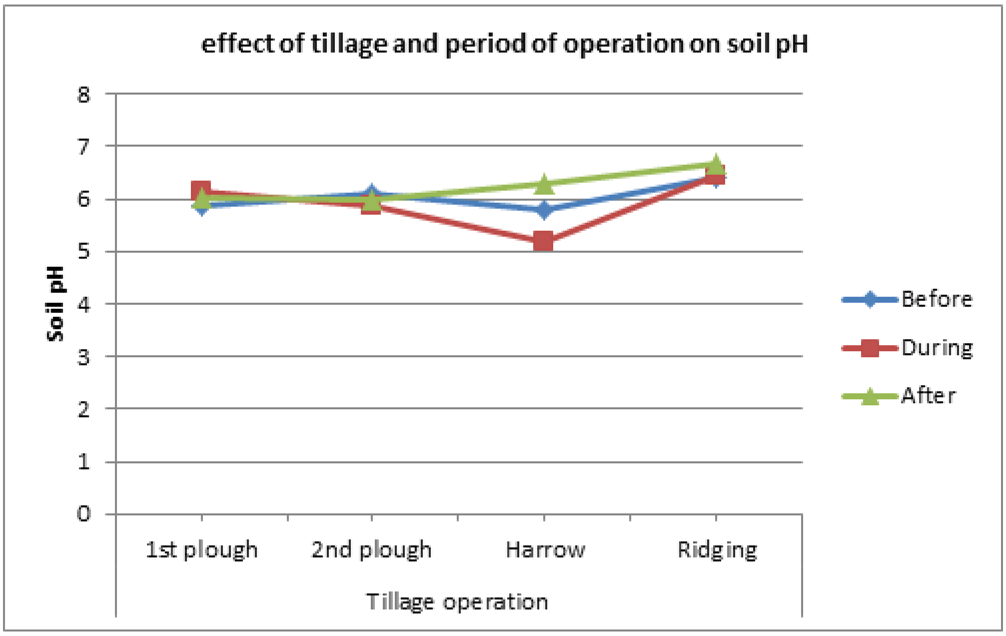

Fig. 3 Effect of Tillage and Period of Operation on Soil Ph for Period

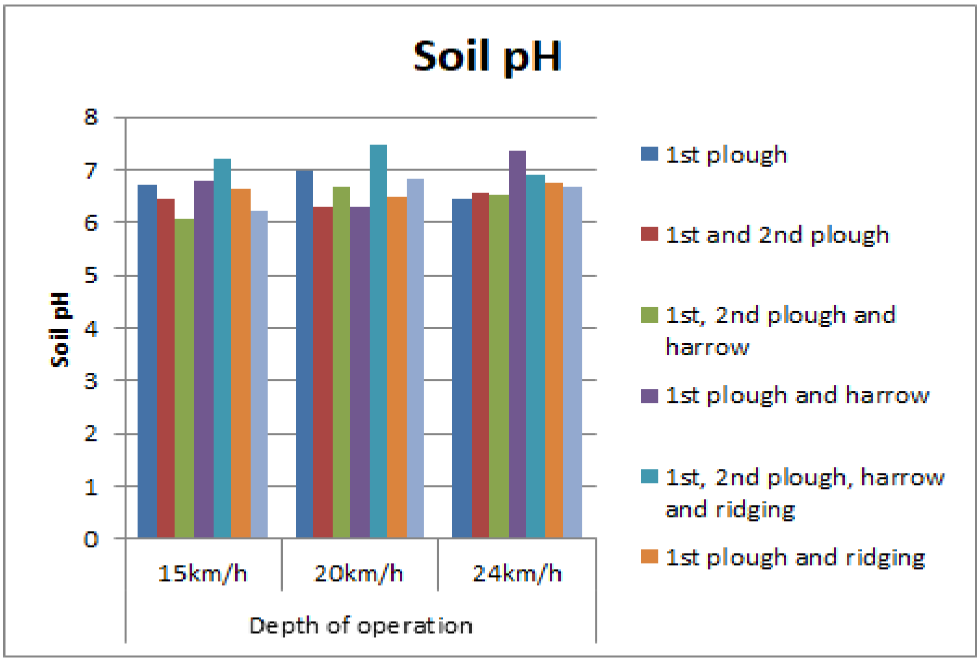

Fig. 4Effect of Tillage and Period of Operation on Soil Ph for Farm Operations

The ridging operation at all depths of cut recorded higher values for the pH levels in the soil and the value have no significant difference from each others. However, the ridging operation at the 10cm depth of cut had the highest value of 6.54 while harrowing operation at depth of cut 20cm had the least recorded value of pH to be 5.55. It can be deduced as shown in the table that there is no significant difference in pH of soil for the following combinations of farmland operation and depth of cut: first plough at 10cm depth and first plough at 20cm depth; first plough at 15cm depth, second plough at 15cm depth and harrowing at 15cm depth; first plough at 15cm depth, harrowing at 10cm depth and harrowing at 15cm depth; second plough at 20cm depth and harrowing at 10cm depth; ridging at 10cm depth, ridging at 15cm depth and ridging at 20cm depth. There are significant differences in soil pH when second plough at 10cm depth and harrowing at 20cm depth where carried out as compared with other combinations of farmland operation and depths of work.

Soil PH is lowest during harrow operation while 1st ploughs operation have the highest soil pH across the three (before, during, and after) period of operation. The four tillage operations have very closed amount of soil pH during operation. However during ridging operation had the highest value of 6.68. The interaction during first ploughing operation and after harrowing operation; before all the operation have lower values recorded with no significant difference in the pH of the soil. Before harrowing operation had the least recorded value of 5.18. From the results of the study as shown in table 2, there are no significant differences in the soil pH for the following timed farm operation: after first plough, before second plough, after harrowing and before harrowing; before first plough and after second plough; during first plough and after second plough; during first plough and during second plough; before second plough and during second plough; after ridging and before ridging. There is significant difference in soil pH during harrowing and after ridging compared with the other timed farm operations.

Before ridging operation at 20cm depth of cut had the highest value of pH level of 7.01. while during second ploughing operation with 15cm depth of cut had the least recorded value of 4.03.

IV. CONCLUSION

Field experiments were conducted to investigate the effect of farm operation types depth of of operation and periods on soil PH of Lagos State University of Science and Technology, Ikorodu Lagos. Conclusion drawn is that before harrowing operation at 20mm depth of cut had the highest **pH** value of 7.01. During second ploughing operation at 15mm depth of cut had the least recorded pH value of 4.03. The pH values obtained before harrowing at 20mm depth and during ridging at 15mm depth are significantly different from every other tillage operating condition;

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