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The Impact of Termite Activity on the Availability of Soil Micronutrients in Tropical Regions

Abubakar Ibrahim Abdulkadir[1]; Sadiq Sani[2]; Sani Umar Uba[3]; Om Prakash Gurjar[4]
[1, 2 & 4] Faculty of Agriculture and Veterinary Sciences, Mewar University, Gangrar- 312901, Chittorgarh, Rajasthan, India.
[3]Department of Soil Science, Faculty of Agriculture, Bayero University, Kano, Nigeria.
Corresponding Author ; Abubakar Ibrahim Abdulkadir

Abstract:- This research aimed to assess the impact of termite actions on the presence of micronutrients in tropical soil. A total of five combined soil samples were gathered from various termite mounds at a depth of 0-20 cm within the premises of Kano University of Science and Technology. The samples were examined for micronutrient levels using Microplasma Atomic Emission Spectroscopy (MP-AES). The findings revealed that the pH of the mounds' soil varied from 6.63 to 8.51, averaging at 7.46, categorizing the soil as slightly acidic to moderately alkaline. The zinc levels ranged from 0.68 mg/kg to 5.38 mg/kg, with an average of 2.52 mg/kg, indicating a high zinc concentration in the soil. Iron content showed a range of 43.72 mg/kg to 121.87 mg/kg, averaging at 78.05 mg/kg, placing it in the "high" range. Manganese levels varied from 7.70 mg/kg to 88.89 mg/kg, with an average of 37.22 mg/kg, also highlighting a substantial amount. Copper concentrations in the mounds ranged from 5.52 mg/kg to 53.33 mg/kg, with an average of 29.86 mg/kg. These outcomes illustrate that termite operations impact the presence of micronutrients, notwithstanding the low organic carbon content and cation exchange capacity of the soils. As a result, it is suggested that combining termite mound soil with organic manure or fertilizers could enhance soil productivity.

Keywords:- *Micronutrients, Termite Mounds, Soil Productivity, Organic Carbon And Cation Exchange Capacity.*

I. INTRODUCTION

Micronutrients, which are metallic chemical elements necessary for plant growth in trace amounts, hold significant agronomic importance akin to macronutrients and serve crucial functions in plant development (Nazif et al., 2006). Zinc (Zn), iron (Fe), copper (Cu), manganese (Mn), and other metallic elements are linked to plant enzymatic systems. For example, Zn aids in growth hormone production, starch synthesis, and seed maturation; Fe is vital for chlorophyll synthesis; Cu plays a key role in photosynthesis; and Mn activates important enzymes and contributes to photosynthesis and metabolism (FFTC, 2001).

The transition from fallow and shifting cultivation to continuous soil cultivation and the adoption of high-yielding crop varieties, which absorb numerous nutrients from the soil, have significantly contributed to micronutrient deficiencies. Furthermore, existing fertilizer guidelines in Northern Nigeria concentrate solely on macronutrients. Prolonged application of only a few macronutrients may deplete the soil's reservoir of other essential nutrients, thereby constraining crop performance (Oyinlola and Chude, 2010).

The management of plant nutrients is primarily influenced by their presence in the soil. Past research has highlighted that soil fertility deterioration, including the decline of microelements, is a prevalent form of land degradation. The pursuit of self-sufficiency in food and cash crop production through irrigation schemes and the implementation of Good Agricultural Practices (GAP) has underscored the need to evaluate soil nutrient levels, particularly micronutrients that have been historically overlooked (Mustapha, 2003). To achieve targeted crop yields, comprehensive information on the microelement status in the study regions' soils is imperative for effective soil fertility management in the future.

Various scholars have suggested that the availability of micronutrients in soils is influenced by factors such as soil pH, organic matter content, adsorptive surfaces, and various physical, chemical, and biological conditions within the rhizosphere (Kabata-Pendias, 2001; Jiang et al., 2009). Substantial areas of arable land in Nigeria have been identified as deficient in micronutrients due to the extensive use of inorganic fertilizers, particularly nitrogen, phosphorus, and potassium by farmers. Insufficient utilization of organic fertilizers and the failure to recycle crop residues are additional factors contributing to the rapid depletion of micronutrients in soils. Acknowledging the severity of these issues and recognizing the declining productivity, the current study was initiated to evaluate the status and distribution of micronutrients and their correlation with select soil properties.

Micronutrient deficiencies were not common in Nigeria, attributed in part to the extensive agricultural systems facilitating soil recuperation and the restoration of macro- and micronutrients previously lost. However, the escalating human and animal population, coupled with the pursuit of food security, has led to the abandonment of traditional extensive agricultural systems in favour of more intensive and scientific methodologies. This transition, combined with the cultivation of new high-yielding crop varieties with high nutrient requirements and farmers' growing awareness of balanced nutrition, has brought to light micronutrient deficiencies in certain Nigerian savanna soils (Mustapha and Loks, 2005).

Numerous research studies have explored the chemical and mineralogical composition of termite mounds (Semhi et al., 2008; Abe et al., 2009). Some investigations have demonstrated discrepancies in clay minerals between mounds and the surrounding soil (Mahaney et al., 1999; Sako et al., 2009), while others have not observed such differences (Jouquet et al., 2005). Understanding the impact of termites on soil fertility is crucial not only for comprehending tropical ecosystem dynamics but also for assessing potential limitations on agricultural productivity (Bruno et al., 2001). The elements analyzed vary across studies, with some lacking precise identification of the termite species responsible for mound formation. Termites play a significant role in altering the physical and chemical characteristics of soil, thereby influencing nutrient and energy flux rates (Abe et al., 2000; Paul, 2006; Coleman and Wall, 2007; Bignell et al., 2011). Termites are accountable for the consumption, digestion, and decomposition of a considerable portion of woody debris in both temperate and tropical regions (Bignell and Eggleton, 2000; Adl, 2003). This investigation sought to assess the micronutrient levels in termite mound soils at Kano University of Science and Technology, Wudil.

➢ *Statement of the Problem*

Soil micronutrients are essential for the health and productivity of tropical ecosystems, influencing plant growth, agricultural yields, and overall biodiversity. However, the mechanisms governing the distribution and availability of these micronutrients in tropical soils remain insufficiently understood. Termite activity has been identified as a significant biotic factor influencing soil properties, given termites' ability to alter soil structure and composition through their foraging and nesting behaviours.

Despite existing research on termite-soil interactions, there is a notable gap in the comprehensive understanding of how termite activity specifically affects the availability of essential soil micronutrients such as iron, zinc, manganese, and copper. This gap poses challenges to developing sustainable soil management practices and optimizing agricultural productivity in tropical regions. Therefore, it is crucial to investigate the extent and nature of termite-induced changes in soil micronutrient availability to enhance our understanding of soil ecology and inform effective land management strategies.

There is little or no existing data on the micronutrient status of termite mounds within the study area. The micronutrient elements include zinc (Zn), Iron (Fe), Copper (Cu) and Manganese (Mn), are associated with the enzymatic systems of plants (FFTC, 2001), suggesting that their bioavailability and take up by plants is essential for crop production (white and Broadley, 2009; White et al., 2012; Makoi et al., 2013). These micronutrients restrict plant growth and reduce crop yields (Bowen et al., 2010; White et al., 2012; Arunachalam et al., 2013).

➢ *Justification*

Ecological Importance: Termites play a pivotal role in tropical ecosystems, functioning as decomposers and soil engineers. Their activities significantly alter soil properties, including nutrient cycling and organic matter decomposition. Understanding these effects is vital for preserving ecosystem functions and biodiversity.

Agricultural Productivity: Soil micronutrients are critical for plant health and crop yields. Insights into how termite activity affects the distribution and availability of these nutrients can guide agricultural practices, enhancing soil fertility and productivity in tropical regions where agriculture is a key economic activity.

Sustainable Soil Management: Understanding termite-induced changes in soil micronutrient availability is essential for informing sustainable land use practices. This is particularly important in the context of climate change and land degradation, where maintaining soil health is crucial for long-term environmental sustainability.

Scientific Contribution: This research will address a significant knowledge gap in soil science and ecology by providing empirical data on the interactions between termite activity and soil micronutrients. Such data can enhance theoretical models of nutrient cycling and soil dynamics in tropical ecosystems.

By examining the impact of termite activity on soil micronutrient availability, this research aims to contribute to a holistic understanding of soil health in tropical regions, supporting both ecological conservation and agricultural development.

Micronutrients have the same agronomic importance and play a vital role in the growth of plants. Micronutrients are required in small quantities, so care should be taken in a way that micronutrients are not found in excess in cultivated soils. Given that, there is a need to assess the micronutrient status of termite mound soils of the study area.

➢ *Objective of the Study*

The objective of this study is to determine the influence of termite activities on the availability of some micronutrient elements of the study soils.

Specific Objectives are:

- To determine some micronutrient elements (Zn, Cu, Fe, and Mn) of the termite mound soil.
- To offer possible suggestions and recommendations for improving soil fertility.

II. MATERIAL AND METHOD

A. *Study Site Description*

The investigation was carried out at Kano University of Science and Technology (KUST) located in Wudil, Kano State, Nigeria. Wudil occupies a position between latitudes 11.59°N and 11.922°N, and longitudes 8.757°E and 8.973°E, approximately 35 km away from Kano along the Kano-Maiduguri road. Wudil experiences an average temperature of 26.5°C, with an annual precipitation of around 755 mm (Olofin, 2008).

B. *Soil Sampling and Handling*

A total of five composite soil samples were acquired from various termite mounds at a depth ranging from 0 to 20 cm. The gathered soil specimens were meticulously preserved in appropriately labelled polythene bags and conveyed to the laboratory for examination. Subsequently, within the laboratory setting, each sample underwent an air-drying process, a combination employing a porcelain pestle and mortar, and filtration through a 2-mm mesh. The sifted samples were then subjected to laboratory scrutiny by established protocols for tropical soils (Mustapha et al., 2003).

C. *Laboratory Analyses*

Soil pH was ascertained in a 1:1 soil-to-water mixture utilizing a glass electrode pH meter. The determination of organic carbon content was executed through the wet combustion technique of Walkley-Black, delineated by Anderson and Ingram (1993). The extraction of extractable micronutrients such as Zn, Cu, Fe, and Mn was carried out using a 0.1M HCl solution (Osiname et al., 1973). These micronutrients were quantified utilizing an atomic absorption spectrophotometer.

D. *Data Analysis*

The amassed data underwent a descriptive statistical analysis encompassing parameters like minimum, maximum, mean, standard error of the mean, and standard deviation. All statistical evaluations were conducted utilizing JMP Pro Version 14 statistical software.

III. RESULTS AND DISCUSSION

A. *Soil Reaction (pH 1:1)*

The outcomes of soil pH are presented in Table 1. Soil pH stands as a pivotal chemical indicator impacting plant growth, microbial activities, and nutrient availability. The soil pH within the mound ranged from 6.63 to 8.51, with a mean of 7.46, positioning it within the slightly acidic to moderately alkaline range based on the Esu (1991) classification. This signifies the presence of a conducive environment for microbial activity and nutrient availability, particularly notable for Zn, Fe, Mn, and Cu. Increased acidity correlates with heightened solubility, thereby enhancing Fe and Mn availability. Conversely, these elements are frequently deficient in plants thriving in alkali soils, where they undergo conversion into insoluble hydroxides and oxides at very high pH levels, rendering them inaccessible. Soil acidity results from various processes including leaching, crop uptake, organic matter decomposition, acid rain, nitrification of ammonium nitrogen, and natural soil-forming processes (McFarland et al., 2001-2005). The data from Table 1 indicate a notable concentration of Fe and Mn at high pH levels, attributed to the soil pH being unsuitable for microbial utilization, emphasizing the pivotal role of soil pH highlighted by Diatta et al. (2014) in micronutrient availability. Notably, Cu and Zn are prone to leaching and deficiency in leached acid soils, whereas they become insoluble and unavailable in alkaline soil conditions. This corroborates the findings of Diatta et al. (2014), underlining the significance of soil pH in micronutrient availability and activity. Optimal nutrient availability is observed around pH 6.5.

B. *Soil Organic Carbon*

The findings concerning soil organic matter are delineated in Table 1. Soil organic carbon, constituting the carbon stored within the soil, serves as a fundamental component of soil organic matter, encompassing plant and animal materials in varying stages of decay. The organic carbon content within the mound soil ranged from 1.60 to 4.22, with a mean of 3.10, aligning generally with Esu's (1991) classification of low to medium organic carbon levels. This low organic carbon content translates to diminished organic matter within the soils. Analogous observations of low organic carbon levels have been reported by Varo et al. (2006) for Nigerian savannah soils, as well as by Mustapha and Nnalee (2007) and Mustapha et al. (2007) for soils within the northern Guinea savannah zone of Nigeria. The limited addition and subsequent loss of organic residues, determining soil organic matter content, contribute to this observed trend, with substantial losses through mineralization (Bins et al., 2003).

C. *Zinc (Zn) Status*

The findings regarding zinc levels are depicted in Table 1, showcasing a range from 0.68 mg kg-1 to 5.38 mg kg-1, with a mean value of 2.52 mg kg-1. According to the critical thresholds established by Esu (1991), all soils fell within the "high" category for zinc status (see Appendix II). However, the results indicate an insufficient range of zinc across all study districts. This inadequacy may be attributed to soil conditions such as low pH and parent materials with high zinc content. Notably, certain soil conditions, particularly high pH levels, diminish zinc availability, leading to a heightened incidence of zinc deficiency, especially in calcareous or lime soils. Contrarily, the present study's soils were neither limed nor calcareous, with pH values in the majority of soils not excessively high to precipitate available zinc.

D. Iron (Fe) Status

The outcomes regarding iron levels are presented in Table 1, showcasing a range from 43.72 mg kg-1 to 121.87 mg kg-1, with a mean of 78.05 mg kg-1, falling within the "high" category according to Esu's (1991) micronutrient fertility rating (Appendix II). The pH of the mound may contribute to the high extractable iron content, given that some soils in the study area exhibit pH levels below 7, enhancing iron solubility. The adequate iron content in the soils may be attributed to parent materials containing minerals such as magnetite, hematite, and limonite, which collectively constitute the bulk of trap rock in the soils (Vijayakumar et al., 2013).

E. Manganese (Mn) Status

The results concerning manganese levels are outlined in Table 1, displaying a range from 7.70 mg kg-1 to 88.89 mg kg-1, with a mean value of 37.22 mg kg-1. This rating falls within the "high" category according to Esu (1991). These values suggest sufficient manganese levels for successful agriculture in the studied soils, surpassing critical limits reported by Lindsay and Norvell (1978), Sillanpaa (1982), and Esu (1991). Notably, the observed values exceed those reported by Mustapha (2003) for ustults in Bauchi state, Nigeria. Sillanpaa (1982) noted that above a soil pH of 7.5, manganese availability decreases significantly due to the formation of hydroxides and chelates. The high content of iron and manganese in the studied soils may lead to complex formation, potentially resulting in drainage and infiltration issues.

F. Copper (Cu) Status

The findings regarding copper levels are detailed in Table 1, exhibiting a range from 5.52 mg kg-1 to 53.33 mg kg-1, with a mean value of 29.86 mg kg-1, classifying it within the high categories as per the rating by Esu (1991). However, it is noteworthy that the threshold for copper deficiency, set at 0.2 mg kg-1, according to Viets and Lindsay (1973), Lindsay and Norvell (1978), and Esu (1991), was not surpassed in the tested soils, indicating sufficiency for optimal crop growth. Various studies have reported the normal copper content of agricultural soils to range between 5 to 50 mg kg-1, with concentrations below 3 mg kg-1 indicating potential deficiency for certain crops (McBride, 1994; Kabata-Pendias and Pendias, 2001). Nonetheless, it is essential to monitor excess copper accumulation in soils, as it can pose toxicity risks to plant growth and development. Lombin (1983a) underscores that available copper contents in Northern Nigeria Savanna soils are adequate, posing no fertility concerns.

G. Effective Cation Exchange Capacity (ECEC)

The outcomes concerning effective cation exchange capacity (ECEC) are elucidated in Table 1. ECEC plays a crucial role in plant nutrient uptake and ion movement, with a strong correlation to the organic carbon and clay content of the soil. Within the mound soil, ECEC ranged between 2.81 cmol(+)/kg to 4.50 cmol(+)/kg, averaging at 3.90 cmol(+)/kg. The generally low ECEC observed is attributed to the low organic carbon content, consequently leading to diminished soil organic matter. The acknowledged significance of soil organic matter (SOM) underscores the dependency of ECEC on SOM, which typically increases with total organic carbon content (Gao and Chang, 1996). The quantity and composition of clay minerals and organic matter emerge as pivotal factors influencing soil ECEC (Mikkelsen, 2011).

Table 1: Soil Micronutrients with Some Chemical Properties

Sample Description	pH (1:1)	OC gkg^{-1}	Zn $mgkg^{-1}$	Fe $mgkg^{-1}$	Mn $mgkg^{-1}$	Cu $mgkg^{-1}$	ECEC cmol(+)/kg
Sample A	6.63	1.70	1.40	79.06	13.63	18.09	4.41
Sample B	6.77	1.60	0.68	98.30	64.76	5.52	4.50
Sample C	7.81	3.83	1.00	47.30	11.12	43.13	3.19
Sample D	7.56	4.22	5.38	43.72	7.70	29.21	2.81
Sample E	8.51	4.12	4.17	121.87	88.89	53.33	3.61
Minimum	6.63	1.60	0.68	43.72	7.70	5.52	2.81
Maximum	8.51	4.22	5.38	121.87	88.89	53.33	4.50
Mean	7.46	0.31	2.53	78.05	37.22	29.86	3.90
SE±	0.35	0.06	0.94	4.93	16.64	8.54	0.48

Key: OC= organic carbon; Zn= Zinc;Fe = Iron;Mn = manganese;Cu= Cupper and ECEC=Effective cation exchange capacity

IV. SUMMARY, CONCLUSION, AND RECOMMENDATION

A. Summary

Micronutrients are integral to plant growth, exerting significant agronomic importance. Termites, through their activities, substantially alter the physical and chemical characteristics of soil, thereby influencing nutrient and energy dynamics. This research endeavours to assess the micronutrient status of termite mound soil within the premises of Kano University of Science and Technology, Wudil. A comprehensive methodology involved the collection of five composite soil samples from distinct termite mounds at depths ranging from 0 to 20cm employing standard laboratory protocols, the investigation encompassed analyses of the physical, and chemical properties, and micronutrient composition of the soils. Results reveal a prevailing trend of soil pH ranging from slightly acidic to moderately alkaline, accompanied by low organic carbon levels, sufficient zinc content, elevated iron levels, adequate manganese, and heightened copper content in the majority of samples. Furthermore, the effective cation exchange capacity (ECEC) of the soil tends to be diminished due to the scarcity of organic carbon content, as unveiled by the research.

B. Conclusion

The synthesis of available data underscores the profound impact of termite activities on soil dynamics, notably evidenced by the significant augmentation of exchangeable cations, micronutrients, and organic matter content. Concurrently, these activities induce a rise in soil pH, thereby mitigating soil acidity, particularly in terms of aluminium concentration. Termites emerge as pivotal agents in the decomposition of organic matter, thereby facilitating nutrient recycling within soil ecosystems and fostering nutrient equilibrium within the soil milieu.

C. Recommendation

To optimize micronutrient solubility and subsequent availability to plants, meticulous attention should be devoted to maintaining soil pH within an optimal range. Although the majority of micronutrients in the soil exhibit adequate levels, precautions should be exercised to prevent potential toxicity concerns. Given the significant role of termites as primary decomposers of organic matter, it is advisable to integrate termite mounds with organic carbon or materials into the soil matrix. This integration aims to augment mineralization processes, bolster micronutrient availability, and promote nutrient balance within the soil environment.

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