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Advances in environmental soil microbiology approaches in Nigeria (A review)

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ABSTRACT

Over the years, environmental soil microbiology has undergone major changes in methodology and approaches which have witnessed considerable progress all over the world especially in the area of agriculture. Approaches including the biochemical and ecological aspects have been developed significantly and contributed vital information on the activities of microbes in the soil. Research in population numbers of specific organisms especially bacteria and fungi was superseded by a focus on biochemical processes which include soil enzyme activities. The advent of molecular approaches has effectuated new insights through the analysis of soil extract DNA which has shown an unexpected diversity for formerly unknown genomes in soil. This paper highlights the current methods and advances in environmental soil microbiology approaches in Nigeria using the existing researches used in peer reviewed publications from search engines and questionnaire responses from researchers. It was observed that despite the fact that the 'omics' approach is highly beneficial and encompassing in environmental soil microbiology researches, some Nigerian researchers are yet to fully embrace the approach.

1.0 Introduction

Environmental soil microbiology can be said to be the scientific study of microorganisms in the soil environment. The soil environment is microbiologically diverse and unique because it contains a vast population of bacteria, actinomycetes, protozoa, algae and fungi which function in biological interactions and biogeochemical reactions concerned with the breakdown of organic matter, weathering of rocks and provision of plant nutrition. Microorganisms can be found across all environments of earth comprising the majority of biodiversity that are crucial for biosphere processes ergo, large numbers of interactions among microbial communities at specific environmental conditions can result in a variety of ecological dynamics. The general knowledge of the physical, chemical and biological characteristics of soils, and the interactions between the biotic and abiotic components as well as the microbial processes / effects of microorganisms on soils and plants has been extended and enriched with a vast amount of detailed findings through intensive research. The concept of soil microbiology to solve the ever expanding list of environmental problems has become increasingly important due to the roles soil microbes play in food security, environmental clean-up, climate change, maintenance of environmental balance amongst others.

Meanwhile, across the globe, in the last few decades, researches have undergone significant progress in soil microbiology. Improved biochemical and ecological ap-

proaches are constantly being developed which have contributed fundamental information on the properties and activities of soil microorganisms (Tian *et al.,* 2016). These improvements became necessary because it was observed that traditional microbiological approaches present severe limitations because only a fraction of the soil bacteria can be cultured using standard methods (Torsvik and Øvreås, 2002). This has led to the advancement of previously existing approaches and methodology which has facilitated the wider study of the microbiome in diverse environments and enhanced the understanding of the metabolic, physiological, and ecological roles of microorganisms. These advancements have ushered in the molecular approach era of soil microbiological research methodology. A diagram representing the evolution of the approaches is shown in figure 1 below.

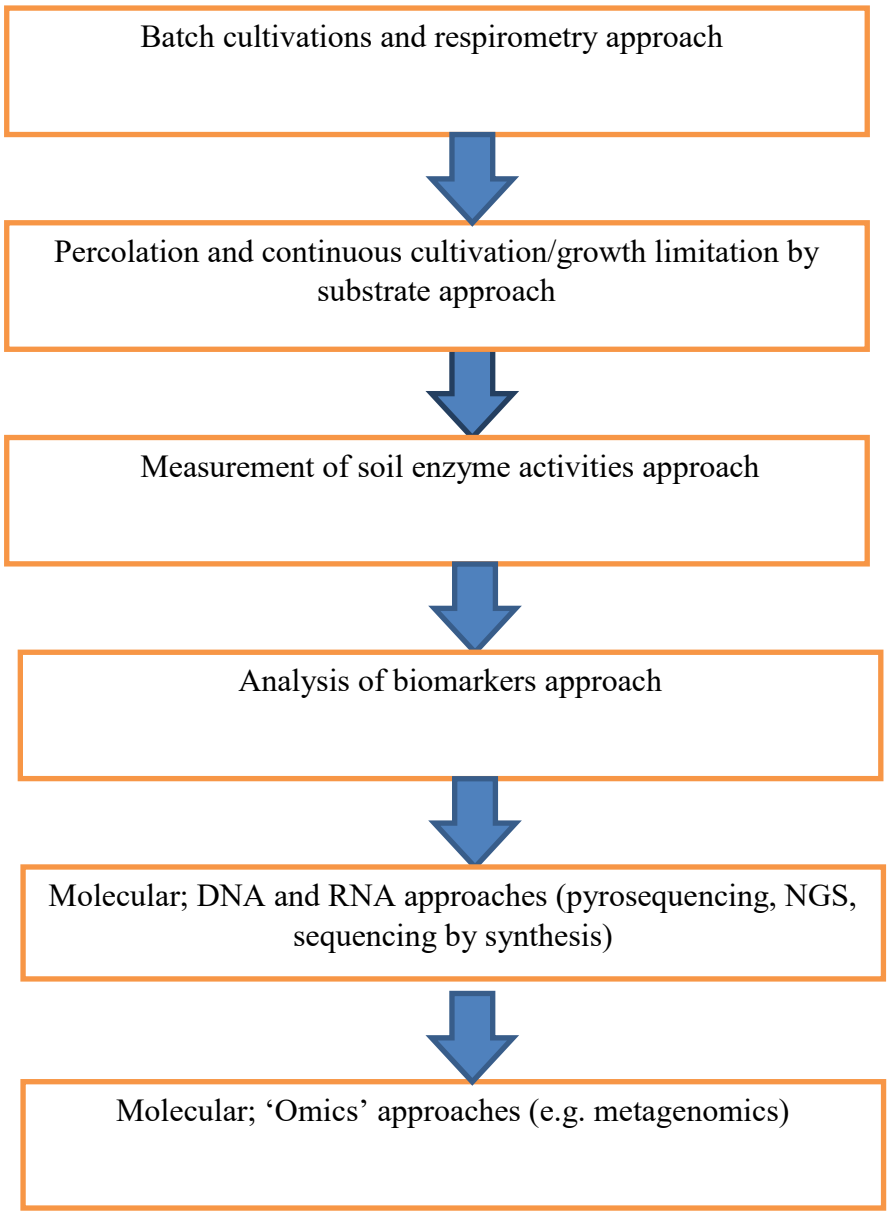


Figure 1; Chart representing the evolution of soil microbiology approaches.
Source: An extraction from; Shrinivas et al., (2019).

The molecular approach consequently, has undergone improvements and has heralded the 'omics' (Delmont *et al.,* 2011) approach era. The 'Omics' approach is a method which includes the study of all molecules of biological origin extracted from an environmental sample. These include; (i) the Genomic approach, which includes DNA copy number assessment, comparative genome hybridization to DNA microarrays, DNA sequencing, mass spectrometry-based genotyping. (ii) Transcriptomics approach which include; Gene expression profiling, DNA micro arrays, Multiples PCR. (iii) Proteomic approach which include; proteomic profiling, mass spectroscopy. (iv) Lipidomics; all lipids, Metabolomics (metabolomic profiling), Glycomics; all cabohydrates. (v)Metagenomic approach; this is a large scale analysis of microbial genomes extracted from soil. (vi).Metatranscriptomic approach; this is the study of genes being expressed by the active soil biota in a sampled soil and is largely based on the analysis of all the RNA transcripts (Rrna, Mrna, miRNA, and tRNA) (Lioa *et al.,* 2019). Of all the 'omics' approaches, the metagenomics approach is seemingly the most popular one used by researchers as seen in soil microbiology research works available on different online academic search engines.

Although soil microbes are the dominant life forms on Earth, the majority of microbes in nature remain unstudied due to limitations in traditional culturing techniques. These techniques can only study organisms that can be grown on artificial media, leaving the rest unknown because of the lack of a universal growth medium and optimal conditions. Metagenomics, which combines traditional microbiology and molecular biology, is a more comprehensive approach to studying all the organisms present in an environmental sample simultaneously, without the need to cultivate them in pure form and study their individual characteristics and morphology Luo *et al.,* (2014).

Metagenomics, the study of the entire genome of the soil biota extracted from an environmental sample, is a great and efficient instrument for assessment of the diversity of complex microbial communities and also to discover a number of new species, genes or novel molecules relevant in agricultural and environmental studies and applications. This approach has helped to examine how microbial populations vary across the different climatic zones and soil types, microbial associations with different plant roots among different species, involvement of microbes in soil pollution and soil management.

However, despite all the benefits of the 'omics' approach, it is yet to be embraced by all soil microbiology researchers. This paper explores the advances in environmental soil microbiology approaches among researchers in Nigeria.

2.0. Methodology

First, a literature review was carried out to identify the relevant articles published on soil microbiology in Nigeria from 2015 using molecular approaches. Google Scholar, PubMed, African Journals Online (AJOL), Scopus, Web of Science, ScienceDirect and Directory of Open Access Journals (DOAJ) databases were explored to identify these studies using the following keywords in English language; Nigeria, metagenomics, soil microbes, soil microbiology, soil microbiology research. A total of 4,673 articles were identified in the initial review but 60 articles were selected to be a good match for the study based on the objective of the study and geographical location.

Secondly, survey forms were generated using Google forms which were distributed virtually to researchers who work in the area of soil microbiology across Nigeria. There were 125 respondents within a seven week period.

3.0. Result and Discussion

A study on the use of molecular approaches in soil microbial investigation among Nigeria researchers was conducted and the results are presented in figure 1 – 5. The data in figure 1 shows that 48% of the number of soil microbial researches done in Nigeria within the period covered by the investigation had actual metagenomics methodology while 52% of the total research work that were investigated were without metagenomics. This result suggest that the level of advancement in adopting metagenomics methodologies in microbial investigation is still below average despite its recognition of being a great and efficient instrument for the assessment of the diversity of complex microbial communities as well as the discovering of a number of new species, genes or novel molecules relevant in agricultural and environmental studies **(**Shrinivas *et al.,* 2019**)**. It is obvious that from the respondent percentage in figure 3, that majority (64%) of the researchers still rely on the traditional / standard plate count method which had over time be reported to its major limitations of not capable of revealing a higher percentage of the total soil inhabiting microbes as against 36% of the population that had applied the molecular based methods in investigating and measurement of soil microbial diversities. This resent development in soil microbial investigation has become more relevant since we cannot link most microorganisms to their metabolic roles increase in capability of sequencing technologies are capable of assisting in characterization and quantifying soil microbial diversities.

The constrain faced by researchers had however been based on the inadequacy of the required equipment (36%) and unaffordable cost implications whereas, 18% based their reasons on no idea about the feasibility and use of the 'omics' methods. while only 9% of the sample suggested it to be encouraging and feasible. Bashir *et al.,* (2014) had however stated that application of metagenomics are largely underexplored for soil microbial communities due to operational challenges. And had also suggested that strengthening our research and increasing our understanding of the soil microbiome through metagenimics tech-

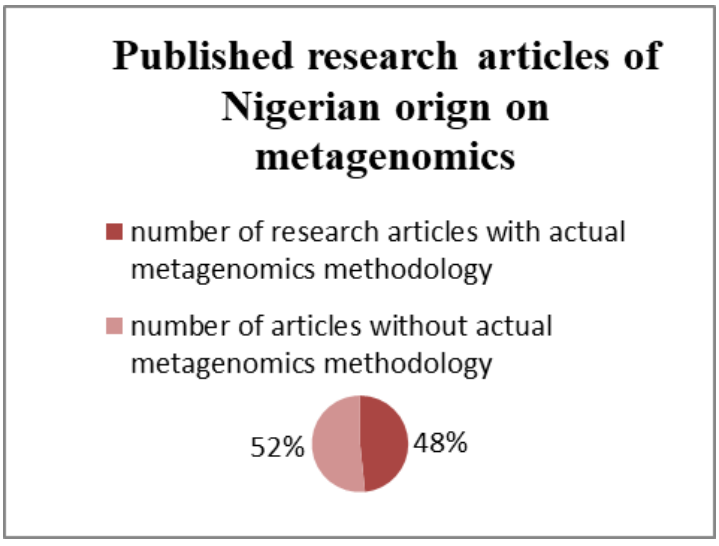


Figure 1. Research question 1 and respondent percentage.

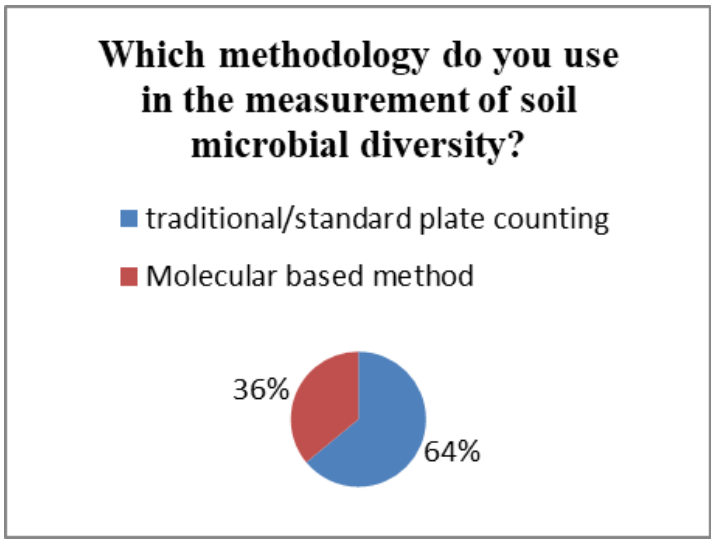


Figure 2. Research question 2 and respondent percentage

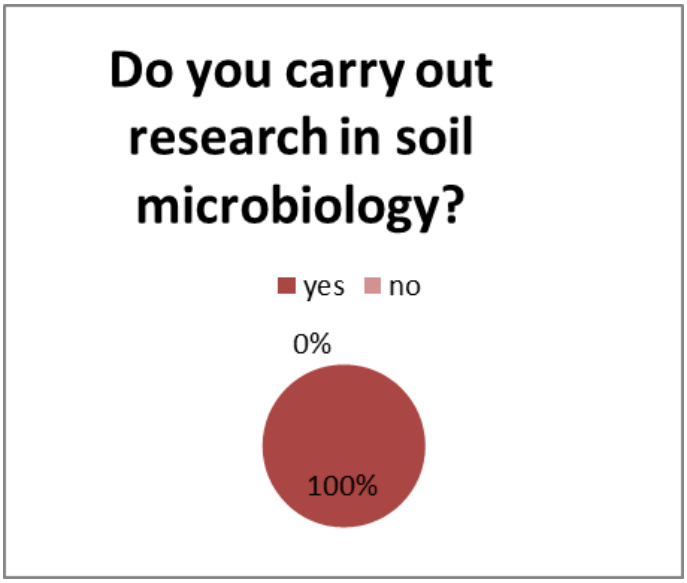


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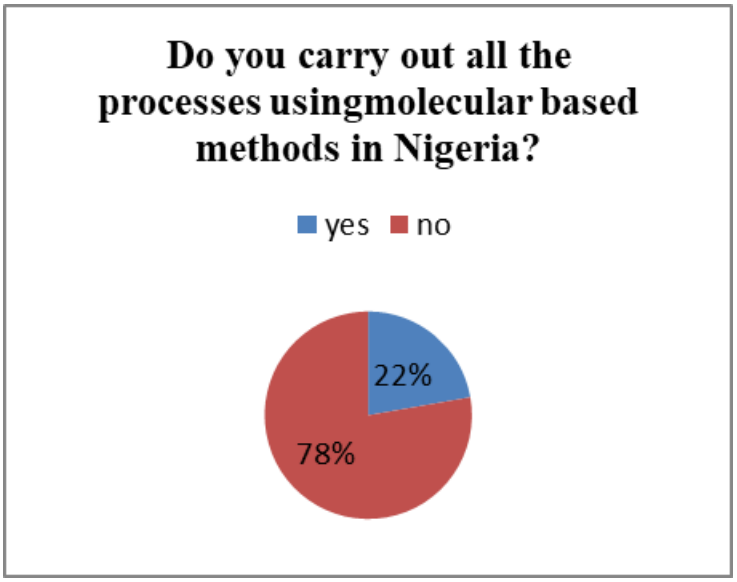
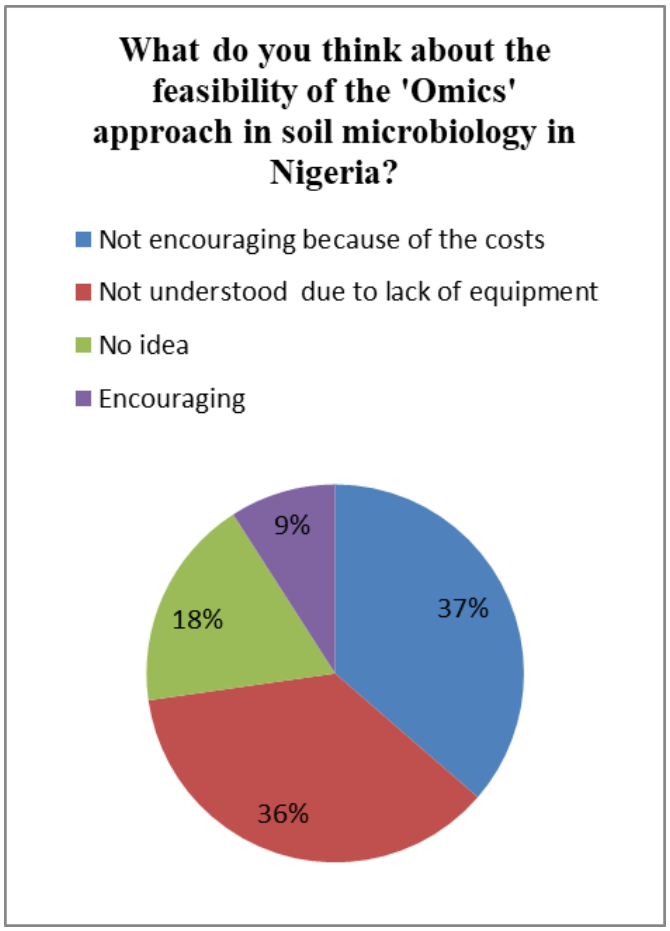


Figure 4. Research question 4 and respondent percentage



niques will accelerate efforts to tackle issues related to carbon sequestration, greenhouse gas mitigation, and ultimately food security.

4.0 Conclusion

While molecular techniques have provided new insights into microbial diversity and function in soil, it represent a significant advance in environmental soil microbiology research in most developed countries due to their ability to identify new species and provide further insights into already known species. Their adoption has been limited in developing country such as Nigeria due to limited resources and lack of access to advanced equipment. As such, traditional methods such as culture-based techniques and morphological characterization still constitute the basic technique for microbial identification in environmental soil microbiology research in Nigeria.

It is important to note that a combination of both molecular and traditional methods will provide a more comprehensive understanding of soil microbial communities and their functions. This approach can also help bridge the gap between developed and developing countries in terms of soil microbiology research and contribute to sustainable

agriculture practices in Nigeria. Therefore, researchers in Nigeria should embrace a multidisciplinary approach to environmental soil microbiology research that leverages both molecular and traditional techniques.

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