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EVALUATING THE USEFULNESS AND ACCURACY OF THE SOIL MICROBIOMETER® AS A TOOL FOR EXTENSION AND RESEARCH IN RESOURCE-CONSTRAINED COUNTRIES

[a]Presley Nickens*, [a]David Ader, [b]Forbes Walker
[a] Smith Center for International Sustainable Agriculture, Institute of Agriculture, University of Tennessee, Knoxville, Tennessee, United States of America.
[b] Department of Biosystems Engineering and Soil Science, Institute of Agriculture, University of Tennessee, Knoxville, Tennessee, United States of America.

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ABSTRACT

Resource-constrained areas are often plagued with soil degradation, resource scarcity, and weak institutional support, yet these areas lack access to the research tools needed for soil testing that would combat declining soil fertility and yields. Thus, there is a need for in-situ research and extension tools in resource-constrained communities. A potential tool to address this need is the microBIOMETER®. The soil microBIOMETER® is an inexpensive, rapid, on-site test that estimates the microbial biomass of a soil sample. The purpose of this research was to test the usefulness of the soil microBIOMETER® as a tool for research and extension in resource-constrained areas. In June 2023, a team of researchers on a United States Agency for International Development (USAID) funded Farmer-to-Farmer volunteer assignment performed several tests and educational trainings in Cambodia using the soil microBIOMETER®. Researchers tested the replicability of the tool by using two different phones (iPhone and Android) to analyze the microbial biomass in two plots. The microBIOMETER® was also used in educational demonstrations at the high school and collegiate levels to evaluate its suitability in an educational setting. There was not a statistically significant difference between the results of the two phones being used to measure microbial biomass, despite differing data being reported by each test. Thus, we suggest the microBIOMETER® is a replicable method for research. Based on our experience using the tool in an educational setting, we propose the microBIOMETER® is best suited for an environment where a rapid, easy, hands-on tool is needed to visually demonstrate the impact of soil management on soil biological activity. The best uses of the microBIOMETER® may be in high school experiments, farmer field days, extension activities, and introductory lessons for undergraduate students.

Corresponding Author: Presley Nickens
Email: pnickens@vols.utk.edu

INTRODUCTION

There is a pressing need for in-situ research and extension tools in resource-constrained communities. Developing countries struggle with low research funding, resource scarcity, and a lack of access to research tools and services; thus, resulting in low agricultural productivity and poverty (Kassim et al., 2022; Rudolph, 2020). To raise agricultural productivity, soil health must be improved through appropriate soil testing and soil management practices. However, developing countries, resource-constrained areas, and rural communities often lack access to the research tools needed for soil testing that would allow them to combat declining soil fertility and soil erosion. Therefore, there is an evident demand for quality, credible, and innovative soil science research in these areas plagued by soil degradation, resource scarcity, and weak institutional support (Lal, 2000). Quantifying the microorganisms present in a particular soil is a promising research procedure to address this need. Soil microbial biomass can be an indicator of soil health; therefore, soil health improvement efforts frequently focus on increasing biological activity (Ziminicki et al., 2020). Soil microbes influence nutrient availability, soil fertility, aggregate stabilization, and soil structure (Sangeetha et al., 2020); furthermore, soil microbial populations are influenced by soil organic matter quantities, soil porosity, plant biomass, temperature, pH level, aeration, and soil moisture (Howe & Peyton, 2021). Measuring microbial biomass can provide a holistic assessment of soil health. This article provides an assessment of a tool used for measuring microbes in soil. The soil microBIOMETER® is a rapid, on-site test that estimates the microbial biomass of a soil sample (microBIOMETER®, 2023). The results provide a measure of micrograms of microbial carbon per gram of soil, as well as a fungal-to-bacterial ratio and the percent of fungi and bacteria. The test was developed by Prolific Earth Sciences and claims to be an easy, inexpensive method to replace costly lab tests and monitor soil health (microBIOMETER®, 2023). This tool may be a promising resource for smallholder farmers who do not have the time or income to send soil samples to a laboratory for extensive and costly testing.

Previous studies have investigated the validity of the soil microBIOMETER®. The microBIOMETER® company claims a 94% correlation between its test results with Chloroform Fumigation Assay (Fitzpatrick et al., 2021). Grosso (2022) studied the correlation between the results of both the microBIOMETER® and Chloroform Fumigation Extraction (CFE), another method used to measure microbial biomass carbon. The study found that the microBIOMETER® did not predict biomass as accurately as CFE, however, the tool could be useful in determining differences among field treatments. Grosso (2022) stated that low readings required the user to add more drops of the microbial solution to the test strip. This may affect the accuracy and replicability of the microBIOMETER® results. Sain (2022) tested the validity of the microBIOMETER® compared to CFE and Substrate Induced Respiration (SIR) microbial biomass measurements on a continuous cotton crop in Jackson, Tennessee at the West Tennessee Research and Education Center. The results indicated that the microBIOMETER® was unable to distinguish between treatments and was less reliable than SIR and CFE.

Although previous studies suggest this tool may not be as accurate as the CFE method, the microBIOMETER® may provide farmers, educators, or extension personnel with limited resources with a method to compare differences in soil health under different soil management practices. The tool is relatively inexpensive and easy to operate, consequently, it has the potential to fill a much-needed gap in areas where soil science research tools are not readily unavailable. This research project seeks to gain a better understanding of the usefulness of the soil microBIOMETER® as a tool for research and extension in resource-constrained areas.

Research Objectives

Our research objectives are as follows:

- Determine the usefulness of the soil microBIOMETER® as a tool for educational demonstrations and farmer extension programs.
- Evaluate the replicability of the soil microBIOMETER® as a research method.

MATERIALS AND METHODS

In June 2023, a team of researchers on a USAID-funded Farmer-to-Farmer volunteer assignment performed several tests and educational trainings in Cambodia using the soil microBIOMETER®. The following steps provide a synopsis of how to analyze a soil sample for microbial biomass using the microBIOMETER®: First, the soil must be sifted through the provided mesh strainer to remove extraneous material. One mL of soil is collected in a plunger, and then compacted to 0.5 mL. A salt-based reagent powder (comprised of sodium chloride and calcium chloride dihydrate) is added to the test tube. Water is added to the capped measuring tube (9.5 mL), and then poured into the reagent powder where it is briefly mixed with the tip of the provided spatula. The prepared 0.5 mL of soil is added to the solution, broken up with the spatula tip, and then whisked for 30 seconds. The test tube will rest for 5 minutes, then should be tapped to sink any debris to the bottom of the tube. After an additional 15 minutes (20 minutes of total resting time), the solution is ready for analysis. Using a pipette, three drops of the prepared solution are added to the test card. Immediately following the addition, the card should be scanned using the microBIOMETER® app (found on the Apple App Store or Google Play).

On June 12, 2023, associates at the Royal University of Agriculture (RUA), Phnom Penh, Cambodia provided soil samples taken from RUA's research plots. The soil samples were collected during the growing season from side-by-side plots in the uplands of northwest Cambodia (Battambang province). The researchers together with farmers are trying to understand the impacts of cover crops on soil health. Our purpose is not to report on the ongoing agronomic research, but only to give a background on the samples. A conventional tillage plot and no-till with a cover crop plot were sampled at depths of 0-5 and 5-10 cm, with four replications for each treatment at both depths. The cover crop treatment contained a mixture of cowpea (Vigna unguiculata) and sun hemp (Crotalaria juncea) that was planted the previous season. The cover crop was crimped down and maize was planted directly into the cover crop residue. The conventional tillage plot also had maize (Zea mays) actively growing at the time of sampling.

To evaluate the replicability and accuracy of the microBIOMETER® as a research method, two researchers simultaneously analyzed the soil samples using the microBIOMETER®. All variables were held constant (water, lightning, microBIOMETER® materials, soil samples, sampling intervals, sampling timing), except for the phone being used to perform the test (Android and iPhone). The data collected was analyzed using R Studio (Version 2022.12.0 +353).

The test was conducted several times during the remainder of the assignment in Cambodia, particularly as a tool for educational demonstrations and farmer extension training. Groups of students at two different high schools near Siem Reap, Cambodia used the microBIOMETER® to investigate soil microbial activity following a lesson on soil health principles. The microBIOMETER® was also used at the National University of Battambang in experiments performed by university students to illustrate and distinguish between healthy and unhealthy soils (defined by their local context).

Finally, staff at the Center for Excellence on Sustainable Intensification and Nutrition at the Royal University of Agriculture were trained to use this tool in hopes that the technology would be further disseminated in farmer extension programs.

RESULTS

This study sought to review the microBIOMETER® as a tool, consequently, it does not aim to evaluate the soil health measures of the collected samples. Due to inadequate establishment time to detect a difference between no-tillage and conventional tillage practices, the microBIOMETER® detected few differences in the soil samples that would indicate improved soil health as a result of no-tillage (Table 1). However, the variability in microbial biomass reported when two different phones were used to analyze samples warranted further investigation (results denoted as Test 1 and Test 2 in Table 1). The results varied when different phones were used with the same lighting conditions in classrooms, which caused concern for the validity of the microBIOMETER®. The results of a two-tailed, two-sample t-test (Classic t-test) using the Welch-Satterthwaite Correction were not statistically significant at the 0.05 alpha level, $t(26.66) = 0.37$, $p = 0.71$. The microbial biomass carbon measured in Test 1 and Test 2 did not vary.

Several tests were performed at schools in Cambodia to determine the usefulness of the soil microBIOMETER® as a tool for education and extension. Staff at the Center for Excellence on Sustainable Intensification and Nutrition (CESAIN) at the Royal University of Agriculture were trained on how to use the microBIOMETER® as a tool for extension. This training process went smoothly, and as a result, the staff were able to effectively use the tool themselves and were equipped to teach others how to use the tool. Some CESAIN staff members assisted with the use of the microBIOMETER® later on during the visits to the high schools near Siem Reap.

At the high school level, the microBIOMETER® was used in science experiments. Students listened to a lecture on soil health, watched a demonstration of how to use the microBIOMETER®, were put into groups of roughly 5 to 10, and were instructed to gather soil samples in groups. The students tested the soil using the microBIOMETER® and were accurately able to follow the instructions given in the demonstration. During the 20-minute waiting period, the activity facilitators were able to discuss the quality of the chosen soil samples with students and prompt conversation on the need for soil testing in agriculture. After the test was completed, facilitators helped the students determine why the microbial biomass carbon varied between soil samples, as a result of differing soil health states.

Table 1. Microbiometer Results.

Treatment	Test 1 ug C/ g	Test 2 ug C/ g	M
T1R1 0-5 cm	42	63	52.5
T1R2 0-5 cm	30	34	32
T1R3 0-5 cm	25	44	34.5
T1R4 0-5 cm	23	26	24.5
T1R1 5-10 cm	32	43	37.5
T1R2 5-10 cm	53	41	47
T1R3 5-10 cm	89	58	73.5
T1R4 5-10 cm	61	38	49.5
T7R1 0-5 cm	31	27	29
T7R2 0-5 cm	43	48	45.5
T7R3 0-5 cm	48	31	39.5
T7R4 0-5 cm	47	45	46
T7R1 5-10 cm	23	22	22.5
T7R2 5-10 cm	21	28	24.5
T7R3 5-10 cm	38	26	32
T7R4 5-10 cm	22	22	22

T1 represents conventional tillage and T7 represents no-tillage with a cover crop. R1-R4 denotes replication one through four. The sampling depth follows the treatment identifier.

At the National University of Battambang, the microBIOMETER® was used as a part of a two-day teaching and training activity. On the first day, students participated in an engaging lecture on soil health and soil biology. At the end of the day, groups of students were instructed to gather two soil samples: one representative of poor soil and one representative of healthy soil (based on the in-situ indicators given during the lecture).

They were also asked to form a hypothesis discerning which soil sample was best and to prepare a presentation on the hypothesis, collection sites, and their reasoning. Students were then trained on how to use the microBIOMETER® and replicated the process with their soil samples. At the end of the experiment, a representative from each group shared the group's results, whether the hypothesis was accepted or rejected, and an explanation of why their findings led to the decision reached about their hypotheses.

DISCUSSION

It was determined that there was not a statistically significant difference between the results of the two differing phones to measure microbial biomass. This suggests that even when separate phones are used to analyze a sample, similar results can be obtained. Thus, we suggest the microBIOMETER® is a replicable method for research. However, our experience using the microBIOMETER® does raise some concerns about the accuracy of the tool. During some of the tests, the microBIOMETER® app asked the user to "add three more drops" of the solution onto the test card. This was likely due to inadequate levels of microbial biomass in the sample to give a reading, which resulted in more of the solution being needed to give a measurement.

The tool was simple, hands-on, gave results quickly, and was easy to train participants on how to properly use it. The short wait time allotted the ideal amount of time to discuss, which provided a good flow for an educational setting. The components included in the microBIOMETER® kit were all needed in the experiments and were of relatively good quality. One setback with the included materials was that the provided sifter (to remove debris from the soil sample) did not work with clays. The soil with higher clay content became lodged in the sifter. The microBIOMETER® does not work well in dimly lit rooms- bright light is needed.

Our experience using the microBIOMETER® in schools was largely positive (Table 2). The tool was an excellent resource to teach students about the scientific method, tangibly show soil health differences, and pique interest in science. High school students, in particular, seemed to be fascinated with the tool and greatly enjoyed the activity. One potential setback of using this tool in a resource-constrained area is that some students may be unfamiliar with how to work a smartphone or use lab equipment (for example, pipettes). On the other hand, students at the university level have had more exposure to scientific tools. Due to the simplicity of the tool, several university students decided to work ahead which led to errors in their experiments. Working step-by-step with the entire group being taught may help alleviate this issue.

Table 2. The Perceived Benefits and Challenges of Using the Microbiometer at Educational Institutions, N=130.

Location	Number of Students	Perceived benefits	Challenges
High School 1	34	Engaged students and piqued interest in science	Soil clay was caught in sifter, so the sample was unable to be sifted
High School 2	51	Provided a tangible method to show differences in soil	Less lighting affected the app's ability to read the card
University	45	Supplied a valid and replicable tool that aided in a scientific experiment	The simplicity of the tool prompted students to work ahead which led to errors

CONCLUSION

We conclude that the microBIOMETER® is a replicable research tool that can be used for educational demonstrations and farmer extension programs in resource-constrained areas. Future research using the microBIOMETER® should test additional soil types, cropping systems, and climates. Specifically, soils with higher organic matter (presumably more microbial activity) should be analyzed. The tool is best suited for an environment where a rapid, easy, hands-on tool is needed to visually demonstrate the impact of soil management on soil biological activity. The best uses of the microBIOMETER® may be in high school experiments, farmer field days, extension activities, and introductory lessons for undergraduate students. This tool may not be the best for users who are expecting specific and accurate levels of microbial biomass, or for audiences who are familiar with more rigorous scientific instruments.

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