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Evaluating eco-friendly soil neutralizers: The use of pulverized eggshells and clam shells in enhancing rice field soil acidity

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Abstract

Soil acidity is an important factor in the yield of rice crops. This article aims to determine the effectiveness of alternative soil neutralizers in agricultural land in the form of utilizing the calcium carbonate and calcium oxide content of pulverized eggshells and clam shells. This study used an independent T-test to determine the difference between the alternative soil neutralizer and commercially- made soil. A total of 45 samples were gathered: these are, along the side of the road, along the irrigation, and away from the road and irrigation. These sites are divided into 4 corners, 1 at the center, and then by 3 based on the depth of the soil sample, separated by 6 inches from top, middle, and bottom. The soil samples were mixed with these neutralizers with a 1:1:2 ratio and recorded a day, three days, and seven days. When mixed with the alternative neutralizers, the results showed a mean of 7.71 pH after seven days while the commercial neutralizers showed a mean of 7.84 pH. The result shows that the alternative neutralizers have a very close value to commercial neutralizers which indicates that they can be used to solve soil acidity at a lower expense. Although the T-test results showed that there is a significant difference between the two neutralizers with a 0.0044 pH value, the difference is just very little and still exhibits an effective result. This implies that the alternative soil neutralizer could be used as an effective, cost-efficient, and eco-friendly substitute.

Keywords: Alternative soil neutralizer, commercially- made soil neutralizer, soil acidity

INTRODUCTION

In the years 2021 to 2022, the Philippines had an estimated 4.8 million hectares of rice land, which yielded approximately 12.5 million metric tons of milled rice [1]. However, local crop production falls short of domestic demand, necessitating food imports to balance supply and demand across different regions [2]. The modern agricultural practices that meet these demands often involve extensive commercial fertilizers, pesticides, and animal wastes, which can harm the environment, including land, air, and water pollution [3], [4]. These activities can also contribute to changes in soil acidity by releasing or concentrating unwanted metals, salts, and acid-forming minerals, which can subsequently contaminate air and water sources.

Soil acidity significantly constrains crop production worldwide, as approximately 50 percent of arable soils globally are acidic [5]. The presence of acidic soils limits the availability of essential nutrients, leading to stunted crop growth, reduced yields, and lower-quality produce [6]. Soil pH, a key parameter for assessing soil properties, provides valuable information beyond whether the soil is acidic or alkaline. It indicates the degree of acidity or alkalinity present in the soil.

Alternative soil neutralizers, such as compost, manure, and agricultural lime derived from natural sources, offer potential solutions for improving soil structure, water retention, and nutrient availability [6]. These alternatives are also environmentally friendly and sustainable. Shells, such as eggshells and clam shells, are rich in calcium and can produce lime (calcium oxide or CaO), a major soil neutralizer [7]. They can serve as substitutes for limestone as a source of lime for soil neutralization. Eggshells and clam shells contain calcium carbonate ($CaCO_3$) and calcium oxide (CaO), alkaline substances that effectively neutralize acidic soils. On the other hand, commercially-made soil neutralizers are specifically formulated to swiftly and effectively balance soil pH. These products often contain a combination of preservative ingredients such as lime, gypsum, or sulfur. They offer convenience and wider availability, making them easily applicable using conventional farming equipment [8]. Various studies have investigated soil's physical and chemical characteristics influenced by various organic farming practices in Asia [9], [10], [11]. Soil acidity indicators are measurable attributes that reflect a soil's capacity to support crop production and perform environmental functions.

Apparently, Barangay Tabunok, Hilongos, Leyte, Philippines is a place that possesses a considerable land area for rice farming within the municipality. It is one of the 51 barangays known for its expansive rice fields, crops, and production, covering 277 hectares of agricultural land [12]. Traditionally, rice fields undergo two harvesting seasons annually to meet the high demand for rice. However, the activities conducted by the community in the rice fields have led to an increase in soil acidity levels, significantly impacting rice production. This study aims to analyze and compare the data regarding the effectiveness of clam shells and eggshells as alternative neutralizers in the soil acidity of different rice field sites of Barangay Tabunok. The findings of the study may provide farmers with valuable insights and techniques to improve their agricultural practices, especially in neutralizing soil acidity and improving soil nutrients. This study also may help improve their productivity; farmers can generate higher agricultural outputs from the same plot of land. Furthermore, the findings from this study can serve as a foundation for future research endeavors in regard to soil neutralizers.

MATERIALS AND METHODS

Limitations of the Study

The study was limited to the soils of different sites in Barangay Tabunok, Hilongos, Leyte. Soil samples were observed and gathered during the dry season of the Philippines (April to May). Due to the availability of equipment and instruments, pH was the only parameter measured to determine the acidity of the collected samples. Shell samples were obtained from household food waste in Barangay Tabunok. The research and evaluation were conducted in the local area of Barangay Tabunok. The evaluation environment was also not controlled, particularly in humidity, weather conditions, and temperature where the samples were stored.

Framework and Research Design

This study is guided by Liebig's Law of the Minimum: This theory, proposed by German chemist Justus von Liebig in the 19th century, states that plant growth is limited by the scarcest nutrient [13]. According to this theory, if a particular essential nutrient is deficient in the soil, it will restrict plant growth regardless of the abundance of other nutrients. This concept highlights the importance of providing all essential nutrients in balanced proportions for optimal plant growth. This study first identifies the materials needed: eggshells, clam shells, soils, and water. Eggshells and clam shells have a liming factor that can help neutralize the pH acidity level of soil, while the soil acts as a reinforcement, as does the water. These materials will then undergo processes and methods such as drying, pulverizing, pouring, and mixing. After successful experimentation, the alternative soil neutralizer will be created and tested in terms of its soil pH acidity level. Hence, the study utilized a randomized design wherein the treatments are assigned completely at random so that each experiment unit has the same chance of receiving any one treatment. The researcher will analyze the effectiveness of clam shells and eggshells as alternative neutralizers in soil acidity of different rice field sites within Barangay Tabunok, Hilongos, Leyte. Additionally, the researcher

will investigate the difference between the neutralizing capability of alternative and commercial soil neutralizers.

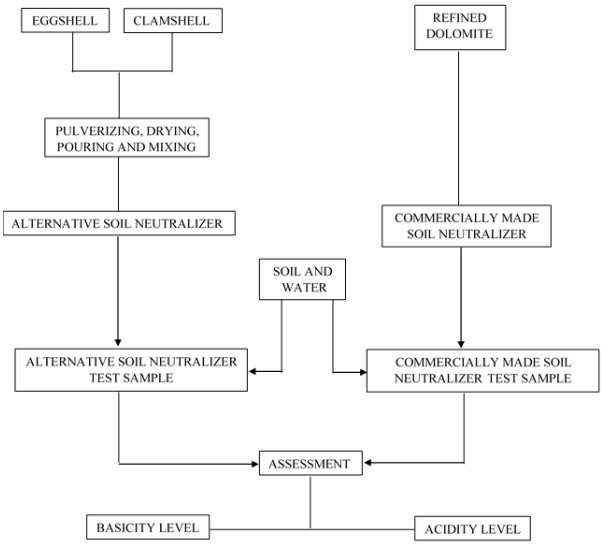

Figure 1. The conceptual model of the study.

Research Equipment and Materials

The essential tools for soil analysis include a shovel for collecting samples, a weighing scale, a mortar and pestle for processing, a spatula for transferring samples, a pH meter, buffer solution for calibration, measuring utensils, a measuring tape/ruler, and plastic food wrap and containers for storage.

Procedures, Methods, and Techniques Used

Clam shells and eggshells, which serve as alternative soil neutralizers, were collected as food waste within the community of Barangay Tabunok. The commercially-made soil neutralizers were purchased from the Hilongos agricultural store in Hilongos, Leyte. Soil samples were collected from various sites within the rice fields of Barangay. These sites included areas alongside the road, the irrigation system, rice fields that are not accessible with the irrigation system, and areas away from the road. For each site, soil samples were gathered from each corner and the central part of the land area to test the soil's acidity (refer to Figure 2). Soil collection will be done from the top, middle, and bottom layers considering that acidity varies at different levels, with a six-inch gap between each layer (refer to Figure 3). Hence, each layer serves as the location of experimental units. All soil samples were undergone a drying process to account for variations in water moisture content across different sites in the rice fields. Once fully dried, a ratio of one-part sample to two parts (1:2) distilled water was added to each sample.

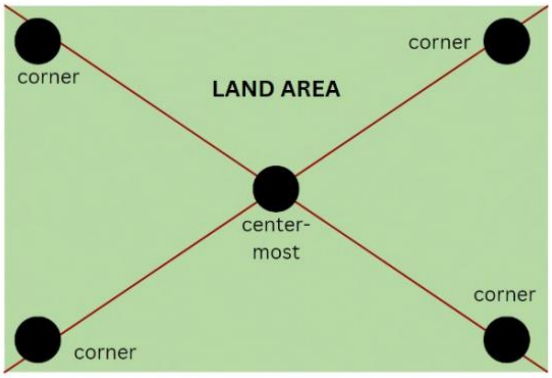

Figure 2. Land area for soil acidity test.

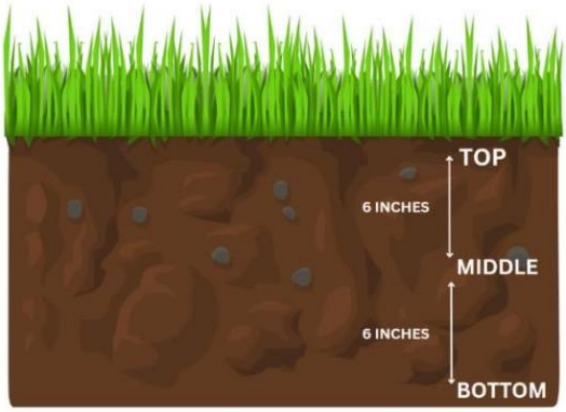

Figure 3. Soil layers for acidity test.

Derivation of Alternative Soil Neutralizer

The shells will be dried for 2-3 days, until fully dried, in an open area under the heat of the sun. Once shells are fully dried, they will be grounded and pulverized separately in a mortar and pestle. The pulverized shells will be stored separately in a sealed clear plastic container for evaluation and experiment.

pH Meter Calibration

Firstly, set the temperature control knob to 25% in the pH Mode. Then, calibrate the two (2) knobs to read 100%. Next, the electrode with deionized was washed with water and pat dry using a clean tissue. The electrode is then placed in a solution of pH 7 buffer, the display must first stabilize, and then calibrate it into 1. The electrode was removed from the buffer and repeated those process to finish the calibration.

pH Value of Soil Neutralizers

Eggshells and clam shells were examined separately to assess the pH acidity of each soil neutralizer component. These neutralizers were diluted with distilled water, concentrating at a 1:2 ratio, meaning one part neutralizer to two parts distilled water. Additionally, a mix of both components was blended at specific proportions to form an alternative soil neutralizer. Initially, eggshell and clam shell soil neutralizers were combined in a 1:1 ratio. Following that, the combined soil neutralizers were diluted with distilled water and concentrated at a 1:2 ratio. Moreover, the pH acidity of each component in the commercially made soil neutralizer was tested separately. The soil neutralizer was then diluted with distilled water and concentrated at a 1:2 ratio for further analysis.

Soil pH Acidity of Each Different Rice Field

Fifteen (15) soil samples were collected from various locations within the rice field to analyze the soil's pH acidity. The study aims to assess soil acidity using a 1:2 ratio. A one-week observation period will be conducted to observe the neutralizing effect of commercial and alternative soil neutralizers in different rice field sites. The pH level of the soils was measured by applying the different types of soil neutralizers. Soil samples were observed at four intervals: twenty-four (24) hours, three (3) days, and one (1) week to collect the mean of the samples.

Data Analysis

After the data gathering for soil pH acidity, it was encoded in Microsoft Excel and formatted for STATA software for statistical computations. This study used descriptive metrics such as percentage (%) and mean average (M). In determining the difference between alternative and commercial soil neutralizers, a

T-test was employed and tested its significance. All statistical computation results were presented in a tabular form and interpreted accordingly.

RESULTS AND DISCUSSION

A total of 45 soil samples were collected from various rice field sites, with 15 samples obtained from each location: alongside the road, alongside the irrigation system, and in areas inaccessible to both sites. The soil collection points considered were the top, middle, and bottom, resulting in a comprehensive analysis. The pH acidity analysis conducted on these samples revealed that the alongside road and not accessible to both site locations exhibited acidic soil conditions, as indicated by the findings (Table 1). However, data obtained from the irrigation system indicated that most of the soil in that area was not acidic. This could be attributed to the constant flow of water, which helps prevent the accumulation of acidity and other harmful substances that could negatively impact the growth of rice crops. This proves the claim in [5] that intensive agricultural land use or extensive rice cultivation contributes to soil acidification.

Table 1. Soil pH level of acidity in different sites of rice fields with soil collection basis.

Soil area		**pH acidity** *(below 7.00 pH is acidic)*		
		Not accessible to both sites	***Alongside the road***	***Alongside the Irrigation***
Upper Left (UL)	Top	6.39	6.04	6.92
	Middle	5.71	6.38	7.04
	Bottom	6.5	6.28	6.96
Lower Left (LL)	Top	6.38	5.82	7.03
	Middle	6.36	6.15	6.94
	Bottom	6.57	6.31	6.92
Upper Right (UR)	Top	6.06	5.78	6.73
	Middle	5.9	5.98	6.91
	Bottom	5.72	6.27	6.9
Lower Right (LR)	Top	5.66	6.33	6.94
	Middle	5.31	6.29	6.92
	Bottom	5.22	6.39	7.03
Center (C)	Top	5.26	5.83	6.55
	Middle	6.88	5.4	6.87
	Bottom	6.74	5.54	6.89

The pH levels of alternative soil neutralizers, such as eggshell, clam shell, and a combination of the two, were tested for their acidity. Figure 4 demonstrates that a pH level below 7.00 indicates acidity. In comparison, the pH level of the eggshell is 8.54, the clam shell is 8.63, and the combined shells register a pH level of 8.72. These three substances are alkaline, as they surpass the 'normal peak' of pH level. This result supports the claims in [6], [14], [15], that these solid waste products have the potential to serve as cost-efficient alternatives to quarried limestone. Similarly, the pH level of a commercially made soil neutralizer was also tested for acidity and the pH level of this commercially made soil neutralizer is 8.92, which is considered alkaline since it exceeds the 'normal peak' of pH level.

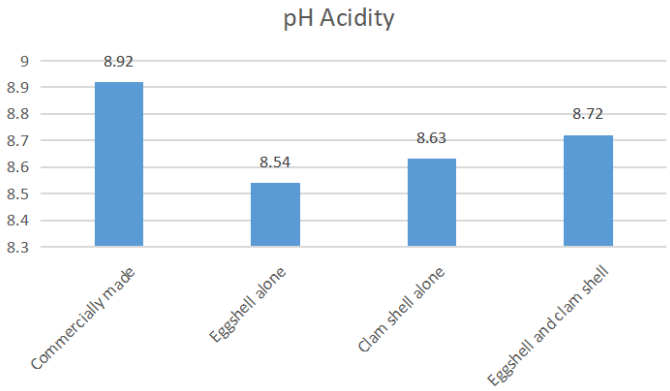

Figure 4. Soil neutralizers pH level.

Table 2 shows that alternative and commercially made soil neutralizers were applied to the soil to test the pH level of acidity within twenty-four hours (24 hrs.). It is worth noting if the p-value is less than or equal to the alpha level of significance, the result is significant, and thus, the null hypothesis is rejected. Note that the null hypothesis in this study is that the alternative and commercial soil neutralizers do not differ in regard to soil acidity. However, as shown in the table, the p-value is <0.001, which is below the alpha level of significance which is 1%, and has a difference of 0.276, which means that in 24 hours, the soil's pH level in alternative neutralizing soil is lower than in commercially-made soil. This indicates that after 24 hours, commercially-made soil has already neutralized the soil acidity to a 7.11 pH level, which is already considered alkaline. In [16] and [17], it is depicted that commercially made soil neutralizers contain some advanced chemicals or ingredients that can significantly decrease the severity of soil acidity and it is usually used as an ameliorant. In that case, commercially made soil neutralizers are definitely fast in increasing pH levels up to alkalinity. Meanwhile, the result of the alternative neutralizer has almost reached the alkaline level and this indicates that it exhibits an effective neutralizing potential within 24 hours. In the study in [18], biological soil neutralizers can also be used for the amendment of soil acidity which is eco-friendly and not costly. Likewise, clam shells and egg shells are depicted to have an effective material in neutralizing soil acidity as well as improving the organic minerals needed for plants [15].

Table 2. Significant Difference between Alternative Soil Neutralizer and Commercially- made soil at 24 hrs.

Variables	***Sample size***	***Mean pH level***	***Significant difference***	***p-value***
Alternative	45	6.831	-0.276	<0.001
Commercial	45	7.108		

Continuous observation was done on the pH acidity level between the alternative and commercially-made soil neutralizers. After three days (3 days), it was found that there was still a significant difference between the alternative soil neutralizers and commercially-made soil with a p-value of <0.001 and a difference of 0.247 which means that the alternative soil is still lower in pH level compared to commercially-made soil neutralizer. However, the alternative soil neutralizer has already reached the alkalinity level, which indicates that the soil acidity has completely diminished as this is the same result as the commercial neutralizer. Hence, the clam shell and eggshell combination is an effective soil neutralizer and can be a substitute for the commercial neutralizer based on the mean pH level computation.

Table 3. Significant Difference between Alternative Soil Neutralizer and Commercially- made soil after three days.

Variable	*Sample size*	*Mean pH level*	*Significant difference*	*p-value*
Alternative	45	7.215	-0.247	<0.001
Commercial	45	7.462		

After seven days, it was observed that the difference between both soil neutralizers is 0.137 with a p-value of 0.004, which is lesser than the actual alpha level of significance which is 1%, which means that the null hypothesis, that there is no significant difference between the alternative soil neutralizer and commercially-made soil is rejected and therefore significant. Thus, it implies that alternative soil neutralizers are less effective compared to commercially made soil. However, based on the results, the difference between the two is very small and considered minimal. Statistically speaking, the p-value is relatively small due to small variations of the raw data of pH levels, however, in the number sense, the difference is mathematically negligible. Hence, this implies that the alternative soil neutralizer has a promising result in neutralizing acidic soil. In that case, an alternative soil neutralizer can be used as a substitute since the effectiveness is almost the same with commercially made and it is not costly plus eco-friendly. This effective result of alternative soil neutralizers is supported in the studies from the literature [14], [15], [17], [18], [19], [20]. In [21], it is portrayed that the effectiveness of alternative soil neutralizers is due to the calcium carbonate ($CaCO_3$) and calcium oxide (CaO) as minerals contained in clam shells and eggshells. Both $CaCO_3$ and CaO are important components of limestone that amend to neutralize soil acidity which is abundant in calcium that is good for plant nutrition [16].

Table 4. Significant Difference between Alternative Soil Neutralizer and Commercially- made soil after seven days.

Variable	*Sample size*	*Mean pH level*	*Significant difference*	*p-value*
Alternative	45	7.706	-0.137	0.004
Commercial	45	7.844		

CONCLUSION AND RECOMMENDATIONS

The effectiveness of the alternative soil neutralizer displayed a direct correlation with commercially produced soil neutralizers. The data demonstrates that the alternative soil neutralizer effectively neutralizes soil across different sites in rice fields. These findings align with previous studies that suggest abundant waste products as promising alternatives to limestone for lime production due to their high calcium carbonate content. Additionally, similar research emphasizes the use of lime, including crushed mollusk shells, to neutralize soil acidity and reduce metal contaminants, ultimately improving soil fertility and oxygen levels. Clam shells emerge as a potentially valuable alternative to quarried limestone. In the context of soil management and agriculture, the effectiveness of alternative soil neutralizers which is a combination of eggshells and clam shells has generated considerable results. The contents of these materials stayed true to their purpose as they efficiently buffered the soil acidity. The experiment exhibited effective results that might lead it to become the next staple soil neutralizer. However, commercially available soil neutralizers still presented greater results. To counter this, alternative neutralizers are still recommended for their cost-efficient, and eco-friendly attributes.

This study suggests that forthcoming studies in agriculture should encompass a thorough investigation of multiple factors. These include initial soil pH, concentrations of neutralizers, treatment duration, soil composition, and environmental conditions, all of which significantly influence the efficacy of alternative soil neutralizers. To advance knowledge in this field, further exploration and experimentation are imperative. This involves determining optimal application methods, and ratios, and assessing the long-term effects of these neutralizers across diverse agricultural landscapes. The quest for understanding does not cease there; ongoing inquiry into the sustained effects and sustainability of these neutralizers remains pivotal. To support this pursuit, this study proposes local initiatives led by Government Units, focused on collecting clam shell and eggshell waste to facilitate large-scale production

of these organic alternative soil neutralizers. To drive adoption and awareness, educating farmers about the efficiency of these alternatives stands as a crucial step. Empowering them to consider reducing reliance on commercially available soil neutralizers can profoundly impact agricultural practices. Looking forward, the study recommends future investigations that delve deeper into studying the enduring impact of soil alkalinity. This involves analyzing plant growth in these soil samples, observing its influence on plant development, and meticulously monitoring fruit and crop yield. This cohesive and continuous exploration aims to pave the way for sustainable agricultural practices and improved soil management. Future researcher can build upon this knowledge base to further deepen their understanding of agricultural practices, resource management, sustainable techniques, and the impact of various factors on productivity.

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