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Leucaena leucocephala and Zeolite-based Fertilizers on the Tuber Yield of Purple Yam (*Dioscorea alata* L.) grown on San Manuel Series

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ABSTRACT

Purple yam (Dioscorea alata L.) is an important staple and cash crop valued for its nutritional content, cultural significance, and potential to enhance food security and rural livelihoods in tropical regions. This study was conducted to assess the influence of zeolites and Leucaena leucocephala on the soil chemical properties of San Manuel series planted with Dioscorea alata, and to evaluate the interaction effect between soil amendments with varying NPK nutrient levels. Results showed that zeolites and Leucaena leucocephala had no significant effect on the soil chemical properties. The Leaf Area Index (LAI) of the yams was not significantly different among the treatments but recorded the highest LAI in yams applied with 80-5-90 NP2O5K20 kg ha-1 with an index of 91 cm² and 94 cm² for A1 and A2, respectively. The tuber yield showed significant differences among treatment means, with yam plants applied with Leucaena leucocephala (A2) being significantly higher than those applied with zeolites (A1). The average yield of yams applied with Factor A2 was 11.1 t ha-1, which was significantly higher than A1 that recorded 8.0 t ha-1. Similarly, the interaction effect between zeolites: fertilizers, and Leucaena leucocephala: fertilizers, significantly increased the yield. The positive control for fertilizers with an application rate of 160-10-180 NP2O5K20 kg ha-1 (B1) resulted in the highest yield with 14.3 t ha-1, which was significantly higher than those fertilizers applied with B0 – control (6.8 t ha-1), B2 -120-7.5-135 NP2O5K20 kg ha-1 (8.1 t ha-1), and B3- 80-5-90 NP2O5K20 kg ha-1 (8.9 t ha-1). This implies that increasing the number of fertilizers with soil amendment (Factor A2) significantly increased the tuber yield.

Keywords: *Leucaena leucocephala*, NPK, soil chemical properties, zeolites

INTRODUCTION

Yam (*Dioscorea alata* L.) is regarded as a crop with high value. Small plots of land, frequently less than a hectare, are used for their cultivation, especially in some parts of the Philippines, such as the Ilocos, Bicol, Central Visayas, Southern Tagalog, and Northern Mindanao. Yams are grown primarily for their subterranean tubers, which vary in form, size, flesh color, and aroma, and are largely produced in the Philippines and Japan in Southeast Asia (FAO, 2006). Yam plants are herbaceous vines that are dioecious and primarily cultivated for their starchy tubers, which are highly nutritious (Vashi et al., 2018). They are considered crucial for food security and are predominantly grown in tropical and subtropical regions (Vashi et al., 2018). It is becoming necessary to sustainably increase yam productivity in Ilocos Region since the demand for yams keeps rising due to the population growth, but on the other hand, reserves of arable land are diminishing and the length of time that land remains fallow is also getting shorter. The increasing need for industrial food on both domestic and international markets, yam is a potential and high-value crop.

Crop productivity is a crucial factor in ensuring food security globally (Preetha & Balakrishnan, 2017). Emerging deficiencies of secondary and micronutrients, in addition to the traditional macronutrients, have been identified as a significant constraint in realizing the full potential of crop yields (Wani et al., 2014) The widely acknowledged conclusion that yams require a high level of natural soil fertility has been reached because of the fall in yam yields under continuous cultivation (O'Sulllivan et al., 2008). Nitrogen deficiency is a perennial problem for most soils. Properly managed, and legume residues are important to increase the total soil N and organic C level in soils, thus the application of *Leucaena leucocephala* is an option since this legume is available locally. Soil organic matter plays a crucial role in yam productivity, which is not compensated for by soil with low organic content by the addition of inorganic fertilizers. All management techniques that will favor the maintenance or increase of soil organic content must be evaluated in yam production systems. In addition, the leaves and pods of *L. leucocephala* are a rich source of nitrogen, phosphorus, and other essential nutrients, making them a suitable organic fertilizer for purple yam cultivation (MacDicken, 1991). Moreover, farmers' perceptions on the use of *L. leucocephala* as a fertilizer for purple yam cultivation have been explored in several studies. These studies have highlighted the potential benefits of using *L. leucocephala*, such as its ability to improve soil fertility, increase crop yields, and reduce the need for synthetic fertilizers.

The use of nanomaterials, such as zeolites, has attracted increasing interest as a potential method to enhance nutrient use efficiency and overall crop performance (Preetha & Balakrishnan, 2017). Zeolites, which are a naturally occurring group of minerals, possess unique physical and chemical properties that make them suitable for agricultural applications. Nanofertilizer technology, including the use of zeolites, has been demonstrated to improve nutrient use efficiency, thereby boosting crop productivity (Al-Juthery et al., 2021; Preetha & Balakrishnan, 2017). In particular, nano-clay-based fertilizer formulations that incorporate zeolites can release nitrogen for up to 1000 hours, significantly longer than the 500 hours typical of traditional fertilizers (Al-Juthery et al., 2021). This extended nutrient release can result in more efficient plant uptake and higher yields (Jayara et al., 2023; Dhage, 2020). Direct application of zeolites to the soil enhances its sorption capacity, reduces acidity, and increases the efficiency of nutrient uptake (Khan et al. 2024). According to Zheng et al. (2019), the application of zeolite or phosphorus alone improved water use efficiency, soil available P, aboveground P uptake, and grain yield in rice.

The NPK fertilization on yam (*Dioscorea alata*) tuber yield is not clearly understood under San Manuel series. San Manuel soils characterized as young soil with less developed soil horizons formed from older alluvial deposits. The usual soil inherent fertility of these soils has low NPK. In the Philippines, few studies have been conducted on the application of *Leucaena leucocephala* as amendments to yam, and no studies have been conducted on the application of zeolite. Thus, this study assessed the influence of zeolites and *Leucaena leucocephala* on the soil physicochemical properties of the San Manuel series planted with *Dioscorea alata*, and to evaluate the interaction effect between soil amendments with varying NPK nutrient levels.

MATERIALS & METHODS

Study Area and Research Design

The study was conducted from May 2023 to February 2024 at Sapilang, Bacnotan, La Union, Philippines situated at 16°43'45.8" North, 120° 23 '09.1" East. The experiment was laid out in two-factor in Randomized Complete Block Design (RCBD) with three replications. The treatments were: Factor A, amendments; A1: zeolite, A2: *Leuceana leucocephala*, and Factor B, nutrient levels; B0: control/ no application, B1:160-10-180 $NP_2O_5K_20$ kg ha^{-1}, B2: 120-7.5-135 $NP_2O_5K_20$ kg $ha^{-1,}$ and B3: 80-5-90 $NP_2O_5K_20$ kg ha^{-1}. Each plot measured 2m x 3m and the distance of yams between rows is 75cm while the distance between hills is 50cm.

Soil chemical characteristics before planting

Soil sampling was taken before planting and after the experiment and analyzed in the laboratory. Chemical analysis includes soil organic carbon (Walkley and Black, 1934), moisture content (Gravimetric method), Soil pH: 1:2H_20 (Potentiometer), Electrical conductivity (Potentiometer), and Available P (Bray & Kurtz, 1945). Before planting, soil analysis showed a soil pH of moderately acidic (5.43), low electrical conductivity of 0.30 dS/m, moisture content of 2.90%, soil organic carbon (SOC) of 1.05 g $kg^{-1,}$ and high available P of 10.04 mg kg^{-1}.

Climtological data

A 2-year summary of monthly average data on rainfall, relative humidity, and temperature for 2022-2023 was obtained from the PAGASA weather station in DMMMSU-NLUC. The annual precipitation recorded was 2,379.2 mm, with August recording the highest precipitation at 619.70 mm, followed by September, July, and May, which ranged from 414.70 mm to 435.60 mm, respectively. December emerged as the driest month with no precipitation. The average annual temperature was 23.15^{o}C, with January and November being the coldest months at 21.33 ^{o}C and 21.40 ^{o}C, respectively. Meanwhile, August recorded the highest temperature at 25 ^{o}C. The annual relative humidity averaged 85.49%, peaking in August at 90.92% and reaching its lowest in April at 79.61%.

Procurement of zeolite and preparation of Leucaena leucocephala

The zeolite was procured from Pangasinan and the rate of application was 15 tons/ha. Split application was employed on the basal and vegetative growth of yam. On the other hand, *Leucaena leucocephala* was applied as a semi-decomposed state at the rate of 8 tons/ha gathered locally at Bacnotan, La Union. The fresh leaves and stalk were chopped finely, stored, and applied as basal.

Land preparation and planting materials

The area was ploughed and harrowed, followed by measurements of the layouts. On the other hand, yam (var. Mindoro) was propagated through setts, which is the upper part of the tuber nearest the stem. Setts were taken from healthy tubers. Furthermore, setts were cut into pieces containing 2-3 buds weighing about 150g each and pre-germinated in the greenhouse. The setts were procured from Benguet State University (BSU) farmers propagated at the Municipality of Tuba, Benguet.

Fertilization

Following the recommendation rate of Hgaza et al. (2010) for *Dioscorea alata*, 160-10-180 $NP_2O_5K_20$ kg ha^{-1} served as the full dose or 100% recommendation rate. The fertilizer materials used are complete fertilizer 14-14-14, muriate of potash (0-0-60), and urea (46-0-0). For 100% recommended rate, 14-14-14: 71 kg ha^{-1}; 0-0-60: 283 kg ha^{-1}; and 46-0-0: 326 kg ha^{-1} were split-applied.

Staking

As soon as sprouts emerged from the soil, staking was done with the use of split bamboos or any available sturdy wood. Vines need stakes for a better display of leaves. This practice was advisable because studies show that the tuber yield was increased. Stakes about 2.0-2.25 meter tall were placed in between hills and around the plots.

Irrigation and weeding management

Drenching methods were employed twice a week from emergence to the tuber growth phase when rainfall was insufficient. Regular weeding was done manually.

Pests and diseases

Observation of the pests and diseases which affected the yam plants was done regularly. As the occurrence of leaf antracnose was observed, benomyl was sprayed as fungicide with 1 or 2 weeks intervals.

Harvesting

Harvesting was done after the leaves turned brownish in color, which was 8 months after planting or 240 DAP. The tubers were harvested manually with the help of digging tools. The collected tubers were cleaned, properly labeled, and placed in plastic sacks and weighed per treatment.

Leaf Area Index (LAI)

The average Leaf Area Index (LAI) was computed using the ImageJ software. Twelve (12) total number of leaves per treatment were randomly taken from 0-100cm of the vines and >100cm, respectively.

Average tuber yield

This was determined by weighing five randomly harvested yam tubers from the middle plants, divided by the total number of sample hills. The average tuber yield was expressed in tons per hectare (t/ha) using the formula below.

$$\frac{Average\ weight\ of\ the\ tubers(kg)}{Sampling\ area\ (m^2)} = \frac{x}{10{,}000\ (m^2)}$$

STATISTICAL ANALYSIS

Analysis of Variance (ANOVA) was conducted to detect the differences among means of each treatment using the Statistical tool for agricultural research (STAR) software package. Each mean was exposed to two-way ANOVA that examined the effect of the treatments. The experiment results were analyzed for studying parameters among treatments, and the significance of differences was calculated using least significant differences (LSD) at $p<0.05$.

RESULTS AND DISCUSSION

Soil Characteristics

The soil chemical properties after harvest are presented in Table 1. The study revealed no profound effects of the treatments on soil pH, Electrical Conductivity (dS/m), Moisture Content (%), and Soil Organic Carbon (SOC). Marginal changes were found in soil pH from plots applied with zeolites (A1) ranging from 5.40 to 5.78, and from plots applied with *L. Leucocephala* ranging from 5.20 to 5.62, which both considered as moderately acidic. This suggests that soil pH has limited influence to raise the moderately acidity level applied with zeolites and *L. Leucocephala.* The influence of soil amendments of factors A1 and A2 or the zeolites and L. leucocephala did not significantly affect the physicochemical properties of San Manuel series planted with *Dioscorea alata* for a total of 240 DAP in Bacnotan, La Union. However, it can be noticed that the Soil Organic Carbon (SOC) before planting has only 1.05 g kg-1 but after harvest, the SOC of all treatments was higher except for A1B3. A longer decomposition process may be studied to further determine the increase of SOC because significant increase of accumulated SOC is evident in long-term leucaena-grass pasture (Alejandro et. al, 2011). Other findings revealed the application of zeolite and plant residues improved carbon pools in density and soluble fractions and carbon sequestration increase by increasing the OC contents in soil (Aminiyan et al. 2016).

Meanwhile, Ube or yam applied with zeolites and full dose of inorganic fertilizers (A1B1) obtained the lowest electrical conductivity (0.29 dS/m), while plants applied with *L. Leucocephala* and 50% recommendation rate obtained the highest EC with 0.74 dS/m. No significant effect was observed from among treatments but nevertheless, the soil EC is in desirable condition as it is affected by soil salinity.

The moisture content of the soil varies for all treatments. These observations have no significant effects on soil physical properties. At the same level of nutrient applied (B2), factor A1 zeolites were found to be the lowest (1.84%) while *L. Leucocephala* obtained the highest moisture content (3.89%). Notably, Factor A2 (*L. Leucocephala)* have >3% moisture levels. Thus, incorporating *L. Leucocephala* has higher moisture levels than Factor A1 (zeolites). In general, low water holding capacity (WHC) of the treatments is due to the coarsed-texture soils.

Table 1. Soil chemical properties after harvest				
Soil pH				
Factor A	**Factor B**			
	B0	**B1**	**B2**	**B3**
A1	5.51	5.52	5.78	5.40
A2	5.62	5.39	5.20	5.41
LSD $_{(0.05)}$	ns	ns	ns	ns
Electrical Conductivity, dS/m				
	B0	B1	B2	B3
A1	0.39	0.29	0.34	0.47
A2	0.34	0.32	0.67	0.74
LSD $_{(0.05)}$	ns	ns	ns	ns
Moisture Content, %				
	B0	B1	B2	B3
A1	2.61	2.48	1.84	2.22
A2	3.70	2.12	3.89	3.13
LSD $_{(0.05)}$	ns	ns	ns	ns
Organic Carbon, g kg^{-1}				
	B0	B1	B2	B3
A1	1.49	1.52	1.31	0.89
A2	1.09	1.21	1.21	1.56
LSD $_{(0.05)}$	ns	ns	ns	ns
Available P, mg kg^{-1}				
	B0	B1	B2	B3
A1	17.00	17.66	16.33	9.00
A2	17.00	15.33	17.33	17.00
LSD $_{(0.05)}$	ns	ns	ns	ns

In the case of soil organic carbon (SOC), no significant differences were observed among treatment means. Plants applied with zeolites (A1) plus varying nutrient levels (B0 to B3) obtained an SOC of 0.89 g kg^{-1} to 1.52 g kg^{-1}. Further, factor A2 (*L. leucocephala*) obtained an SOC of 1.09 g kg^{-1} to 1.56 g kg^{-1} from different levels of nutrients. This suggests that the influence of soil amendments or varying nutrient rates on the SOC has no significant effects. The lack of tuber yield responses to other treatments such as A1B0, A1B2, A1B3 (zeolites+ nutrient levels) and A2B0, A2B2, A2B3 (L. leucocephala + nutrient levels) might be due to pests and diseases as supported by the study of Sotomayor-Ramirez et al., (2003) in yams. In this study, some plants were infected with anthracnose diseases. Further, the response of the yams to fertilization may be affected by many factors such as climatic growth conditions, cultural practices, and soil (Below, 2001).

Leaf Area Index (LAI)

The Leaf Area Index (LAI) is presented in Table 2. Analysis of Variance shows no significant differences observed among the treatment means. However, Factors A1 and A2 represent the highest leaf area index applied with 50% recommended rates (B3) with LAI of 91 cm^2 and 94 cm^2, respectively.

On the other hand, A1B2 revealed the lowest LAI of 57 cm^2. This implies that the application of factors A and B did not affect the Leaf Area Index of yams.

Table 2. Leaf Area Index, cm^2				
Factor A	**Factor B**			
	B0	**B1**	**B2**	**B3**
A1	77	73	57	91
A2	80	85	82	94
LSD $_{(0.05)}$	ns	ns	ns	ns

Tuber Yield

The tuber yield showed significant differences among treatment means using two-way ANOVA (Table 3). Yam plants applied with *L. leucocephala* (A2*)* are significantly higher than those plants applied with zeolites (A1). The average yield of yams applied for Factor A2 obtained 11.1 t ha^{-1} which is significantly higher than Factor A1 that recorded 8.0 t ha^{-1}.

Table 3. Tuber Yield	
Factor A	**Yield, t ha^{-1}**
A1	8.0^b
A2	11.1^a
Factor B	
B0	6.8^b
B1	14.3^a
B2	8.1^b
B3	8.9^b
Means with the same letter are not significantly different at p<0.05, LSD.	

Similarly, the interaction effect between zeolites: fertilizers, and *L. leucocephala*: fertilizers significantly increased the yield. The positive control for fertilizers with an application rate of 160-10-180 $NP_2O_5K_20$ kg ha^{-1} (B1) resulted in the highest yield with 14.3 t ha^{-1}, which is significantly higher than those fertilizers applied with B0 – control (6.8 t ha^{-1}) , B2 -120-7.5-135 $NP_2O_5K_20$ kg ha^{-1} (8.1 t ha^{-1}), and B3- 80-5-90 $NP_2O_5K_20$ kg ha^{-1} (8.9 t ha^{-1}) This implies that increasing the amount of fertilizers with soil amendment (Factors A1 and A2) significantly increased the tuber yield.

CONCLUSION

The application of zeolites and *Leucaena leucocephala* to yam plants did not significantly influence the soil chemical properties of the San Manuel series. Factor A (*Leucaena leucocephala*) soil amendment obtained a higher yield which is significantly different from Factor B (Zeolites). Thus, application of *Leucaena leucocephala* as soil amendment to purple yam could be recommended for farmers aiming to improve yields sustainably. Further research could explore optimizing application rates and combining *Leucaena leucocephala* with other amendments or fertilizers to maximize productivity while maintaining soil health. Furthermore, fertilization significantly increased the fresh tuber yield. This indicates that the recommended dose of 160 kg N ha^{-1}, 10 kg P ha^{-1}, and 180 kg K ha^{-1}, as proposed by Hgaza et al. (2010), can be applied to San Manuel soils in La Union. Similarly, the study by Ettien et al. (2009), which recommended a rate of 120 kg N ha^{-1}, 38 kg P ha^{-1}, and 103 kg K ha^{-1} for Dioscorea rotundata, presents a comparable fertilization guideline.

Declaration by Authors

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