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ORIGINAL ARTICLE

Evaluating agrominerals and soil improvers for cucumber and bean crops in Moa municipality

Evaluación de agrominerales y mejoradores de suelo para el cultivo de pepino y habichuela en el municipio de Moa

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Abstract

The lateritic ferrous soils of Moa have low agricultural productivity. This study is aimed to evaluate applying agrominerals and soil improvers, based on three experiments carried out in two organoponics from the locality. Formulations based on zeolitized tuffs loaded with ammoniac residual and calcilutites were applied on cucumber and bean crops, and on cucumber crops, formulations based on zeolitized tuffs loaded with ammoniac residual and mixed with glassy tuffs. It was showed that formulations achieved an increase in the yield of bean and cucumber crops, Puerto Padre Variety, demonstrating the viability of using this agro-mineral. These results contribute to environmental sustainability and encouraging the adoption of more sustainable practices.

Keywords: agro mineral, soil improver, cucumber crop, bean crop, tuffs, calcilutite, ammoniac residual

Resumen

Los suelos lateríticos ferrosos de Moa son de baja productividad agrícola. El presente trabajo tuvo el objetivo de evaluar la aplicación de agrominerales y mejoradores de suelos, a partir de tres experimentos realizados en dos organopónicos de la localidad. Se aplicaron formulaciones a base de tobas zeolitizadas cargadas con residual amoniacal y calcilutitas en cultivos de pepino y habichuela, y formulaciones a base de tobas zeolitizadas cargadas con residual amoniacal y mezcladas con tobas vítreas, en cultivos de pepino. Las formulaciones lograron incrementar el rendimiento de la habichuela y del pepino variedad Puerto Padre evidenciando la viabilidad del uso de este agromineral. Los resultados contribuyen a la sostenibilidad ambiental y fomentan la adopción de prácticas más sostenibles.

Palabras clave: agromineral, mejorador de suelo, cultivo de pepino, cultivo de habichuela, tobas, calcilutitas, residual amoniacal

1. INTRODUCTION

Industrial rocks and minerals have always held an important place in the economy due to their widespread use across various industries. They are also extensively distributed across the Earth's surface, with some playing an essential role in soil development and fertility (Leyva et al., 2022).

On the other hand, food production finds its most practical expression at the territorial level, requiring an agricultural management model that emerges locally. Urban, suburban, and family agriculture represent important local components in food production.

Within Cuba's economic context, the Food Sovereignty and Nutritional Education Plan (SAN), approved in 2020, includes the fundamental objective of enforcing what is established in the Constitution (Fonseca, 2024).

Urban agriculture (UA) offers numerous advantages when practiced appropriately and under safe conditions. However, when developed in unsuitable soils, this solution carries inherent risks to human health and the environment.

One health risk associated with UA is the transfer of toxic substances, such as heavy metals, to food crops grown in urban areas through absorption from contaminated soils, air, or water (Giuffré et al., 2005; Ribeiro et al., 2015; Amaya-Gómez, 2018; Cotta et al., 2021; Burbano-Criollo et al., 2022).

In Cuba's case, urban agriculture (UA) has been a successful response to the food and economic crisis facing the country. Additionally, it has had a positive impact on the local economy, environment, and society, and has been valued as a way to promote food sovereignty and sustainable development (Companioni et al., 2001; Herrera-Sorzano & Herrera, 2009; Lopes et al., 2013).

The current fertilizer crisis demands alternatives to timely address agricultural production problems and prevent future food shortages. Hernández (2012) notes that soil conditioners are products added to soil to positively influence its structure and fertility. Unlike fertilizers, they do not contain many plant nutrients.

These products can be used independently or in combination. Their use results in more workable soils, improved air-water relationships, optimized nutrient conditions, and increased humus content. In this context, the use of agrominerals has been considered.

An agromineral is a soil amendment added to positively influence soil structure, physicochemical characteristics, and fertility. They help retain moisture, reduce nutrient loss, regulate pH in acidic soils, and soften compacted and hard soils (Orozco-Melgar & Cuza-Fernández, 2022).

Many minerals and rocks can be used in the production of agrominerals. In this regard, Holguín province has significant potential, with more than one hundred occurrences and deposits of zeolitized and vitreous rocks distributed across all its municipalities. It also has deposits of phosphated limestones in Banes municipality.

Another widespread mineral resource is carbonate rocks, not always considered for liming acidic soils (Leyva et al., 2022). The productivity of soils in Holguín province is shown in Table 1; these are classified into three categories according to the soil laboratory's standards (Arjona-Mendoza, 2024).

2. MATERIALS AND METHODS

The study was conducted in Moa municipality, located on the northeastern coast of Holguín province (Figure 1). It borders Baracoa municipality to the east, Yateras to the south, Frank País and Sagua de Tánamo municipalities to the west, and the Atlantic Ocean to the north.

A three-stage methodology was implemented (Figure 2). The first stage involved reviewing and evaluating results related to urban and suburban agriculture development and agricultural progress in Moa municipality. The second stage included field work for raw material identification, location, and extraction; analytical methods for chemical and mineralogical characterization of materials; and agromineral production from available materials (Figure 3). The third stage assessed the effect of agromineral application on bean and cucumber crops in Moa's ferralitic soils.

Table 1. Agricultural production categories of soils of the Holguín province

Municipality	Very productives		Productives		Unproductive		Very unproductives		TOTAL ha
	PRODUCTIVE POTENTIAL								
	> 70%		70%-50 %		50-30 %		< 30%		
	ha	%	ha	%	ha	%	ha	%	
C. García	5681,25	9,22	13871,75	22,53	13915,5	22,6	28110,625	45,65	61579,125
Gibara	56,25	0,13	14342,8	32,21	12454,45	27,97	17677,975	39,69	44531,475
Holguín	787,5	1,4	5253,125	9,35	10791,98	19,22	39338,355	70,03	56170,96
Cacocum	...	...	3610,625	5,53	27773,694	42,52	33929,556	51,95	65313,875
R. Freyre	140,675	0,25	4443,125	7,91	14378,625	25,6	37196,625	66,24	56159,05
Báguano	268,903	0,35	7493,681	9,74	26230,01	34,08	42961,229	55,83	76953,823
U. Noris	170,374	0,2	7675,319	9,18	48448,633	57,95	27308,615	32,67	83602,941
Banes	409,375	0,59	8213,3	11,85	18328,51	26,44	42375,215	61,12	69326,4
Cueto	...	...	833,125	2,75	18306,375	60,17	11282,125	37,09	30421,625
Mayarí	3579,375	2,98	2566,21	2,14	17940,595	14,95	95894,9	79,93	119981,08
F. País	...	...	3773,125	8,2	5895	17,81	36364,37	78,99	46032,495
S. Tánamo	...	...	2886,25	3,7	3382,875	4,34	71664,5	91,96	77933,625
Moa	...	...	...	...	193	0,29	66746,2	99,71	66939,2
Antilla	...	...	...	...	3700	43,72	4762,5	56,28	8462,5
PROVINCE	11093,702	1,3	74962,435	8,77	221739,247	25,5	555612,79	64,43	863408,174

Source: Direction Center of Agriculture of the Holguin Province

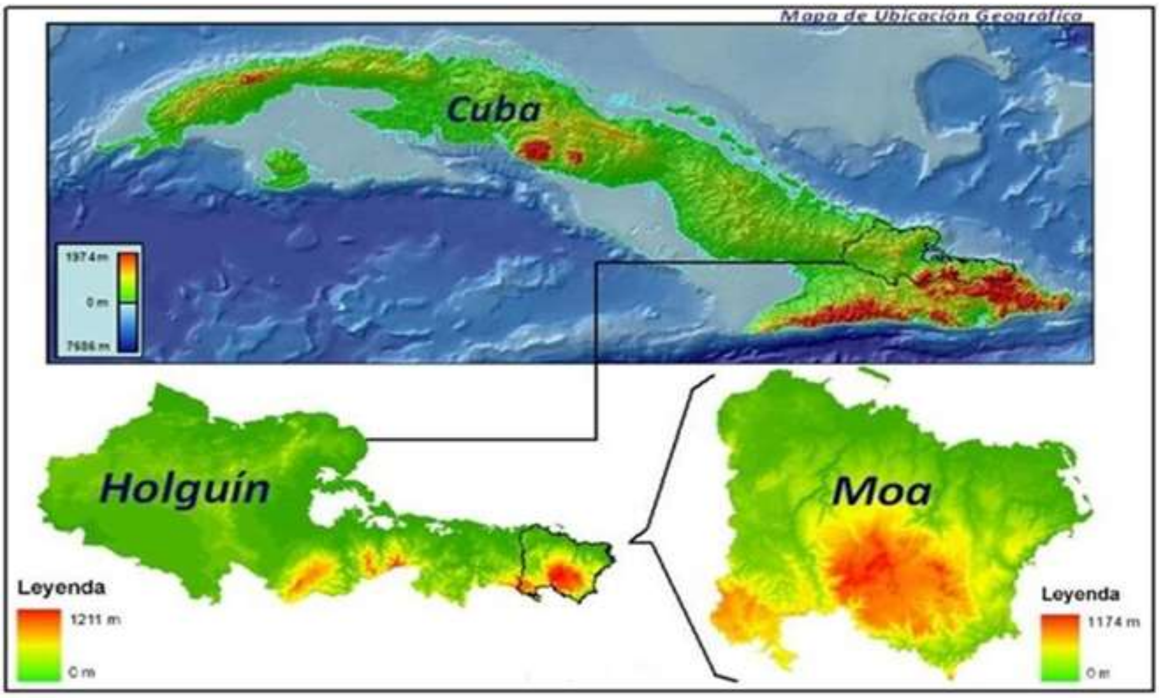

Figure 1. Geographical location of the municipality of Moa (Cruz-Ramírez, 2019).

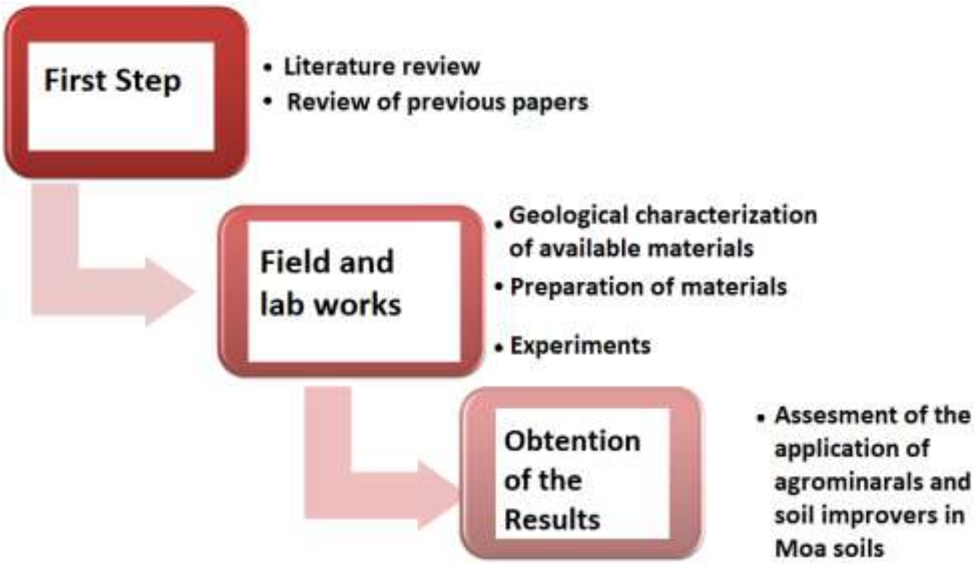

Figure 2. Steps of used metodology.

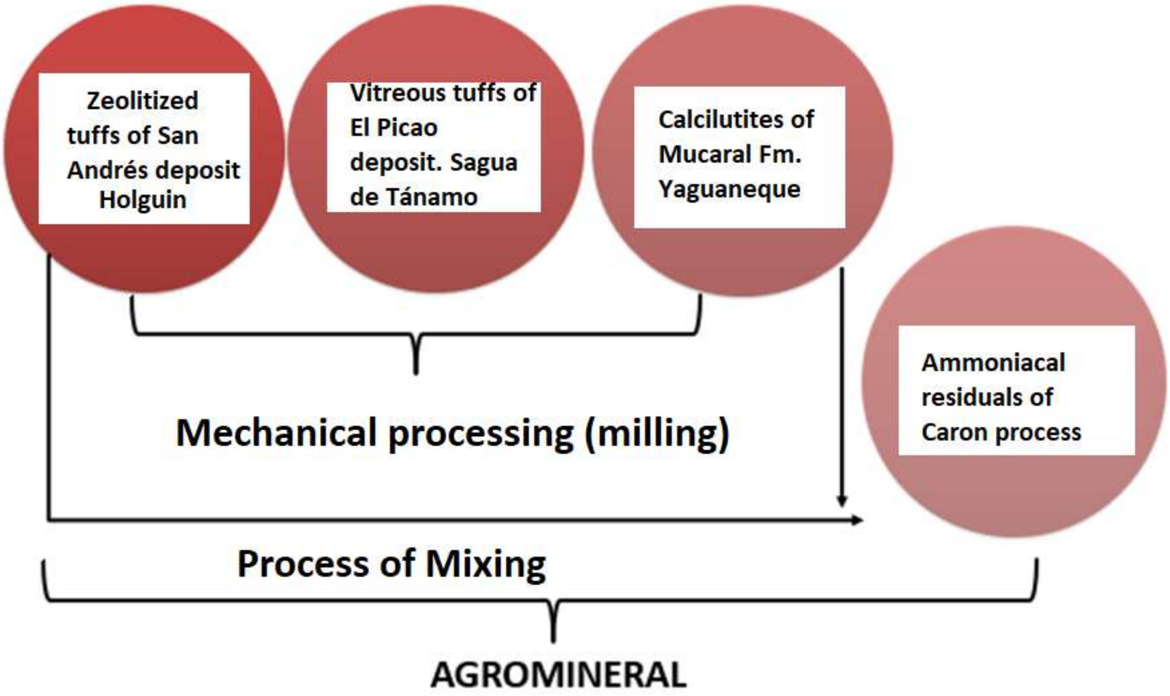

Figure 3. Scheme of agromineral obtention.

Chemical analysis of tuffs (zeolitized and vitroclastic) determined eight components in each: SiO_2, TiO_2, Al_2O_3, Fe_2O_3, CaO, MgO, Na_2O, and K_2O using X-ray fluorescence. Ammoniacal waste from the CARON metallurgical process at Ernesto Che Guevara factory served as the ammonium source for exchange with zeolitized tuffs. Chemical analysis of the waste was performed at Moa's Nickel Research Center (CEDINIQ) using atomic absorption spectrophotometry for Ni and Co determination, and titration for ammonia quantification in liquors.

Calcilutite samples were processed at the geoscience laboratory of Angola's Geology Institute, which also analyzed heavy metal composition of all materials. Three experiments were conducted:

1. Testing a soil conditioner based on ammoniacal waste-charged zeolitized tuffs and calcilutites in bean cultivation. Planting occurred in cool evening conditions with adequate moisture and quality seeds.

2. Applying carbonate rocks (from Mucaral Formation, Yaguaneque locality) to lateritic soils for cucumber cultivation. For liming, plots were divided: Variant A received 2 kg calcilutites, Variant B 4 kg, while the control received no pH correction or fertilizer. A 50/50 mixture of calcareous calcilutites and ammoniacal waste-charged zeolitized tuffs was subsequently tested.

3. Evaluating ammoniacal waste-charged zeolite mixed with vitric tuffs for cucumber cultivation at Miraflores organoponic garden.

The agromineral formulation used:

- ✓ Zeolitized tuffs from San Andrés deposit (Holguín)
- ✓ Vitriclastic tuffs from El Picao deposit (Sagua de Tánamo)
- ✓ Calcilutites from Yaguaneque region (Moa)

Chemical composition data (Table 2) were sourced from Almenares-Reyes (2011). All cases used CARON process waste liquor from Comandante Ernesto Guevara nickel-cobalt production plant, with initial concentration of 1,951.6 mg/L.

Table 2. Chemical composition of the geological material used in the formation of agrominerals

Composite sample	Content (%)								
	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	MgO	Na_2O	K_2O	PPI
San Andrés tuffs	65,55	0,276	11,75	1,43	2,824	0,947	1,376	1,677	14,15
El Picao tuffs	60,86	0,49	13.63	4,58	5,34	2,64	1,87	2,27	8,83
Calcilutites of Yaguaneque	<19	0,057	1,5	1,59	46,67	1,45	<0,3	<0,1	...

3. RESULTS AND DISCUSSION

The cation exchange process between zeolitized tuffs and ammoniacal waste demonstrated the zeolites' high ammonium removal capacity. Chemical analysis results (Table 3) indicate 99% removal effectiveness.

Table 3**.** Chemical composition of ammoniacal waste treated with zeolitized tuffs

Waste liquor	NH_3 Content
Initial waste	1951,6 mg/L
Treated with zeolitized tuffs	13,6 mg/L

Heavy metal contents in the geological formulation materials and resulting agromineral are shown in Table 4, revealing the waste liquor's effect in reducing certain heavy metal concentrations in the agromineral.

Table 4. Heavy metal contents

Composite sample	Content (ppm)					
	Pb	**Cd**	**Ni**	**Co**	**Cu**	**V**
Zeolitized natural tuff	6,17	0,058	24,2	2,74	8,44	16,5
Vitroclastic tuff	7,55	0,13	15,0	7,96	31,9	12,7
Calcilutites	3,48	0,068	27,9	8,44	13,0	32,1
Agromineral	4,86	0,076	12,6	2,31	9,72	16,8

3.1. Evaluation of zeolitized tuffs+ammoniacal waste+calcilutites agromineral in bean cultivation. University of Moa organoponic

The treatment proved effective, resulting in nearly complete seed germination (only three plants failed to germinate) and healthy plant development (Figure 4).

Figura 4. Beans plants. (A). 15 days; (B). 27 days.

As shown in Table 5 (Garlobo-Plutin, 2023), ammonium-charged zeolite-based agrominerals effectively increased bean production. Zeolites are known for their nutrient retention and gradual release capabilities, promoting plant growth. Compared to the control group, ammonium-charged zeolites as soil supplements significantly increased bean yields across four harvest cycles, indicating their substantial contribution to crop productivity.

Table 5. Results of beans crop (Garlobo-Plutin, 2023)

Samples	First Harvest (53 days) (kg)	Second Harvest (61 days) (kg)	Third Harvest (65 days) (kg)	Fourth Harvest (69 days) (kg)	Total (kg)
E-1	1,35	1,60	0,84	0,54	4,33
E-2	1,75	2,20	1,24	0,93	6,63
E-3	3,50	4,15	2,32	1,45	11,42

E-1: Plants planted in untreated lateritic soil; E-2: only liming with calcilutites as a soil improver; E-3: combination of liming and agromineral.

Soil liming with calcilutites also proved effective as a complementary measure, improving production even when used alone, warranting further investigation into calcilutites as pH correctors.

3.2 Evaluation of ammoniacal waste-charged zeolitized tuffs+vitric tuffs agromineral in cucumber cultivation (Miraflores organoponic)

Table 2 data confirm the highly effective interaction between zeolitized tuffs and ammoniacal waste, removing 99% of ammonium from the waste liquor (initial concentration: 1951.6 mg/L). This exceptional ammonium removal capacity is particularly valuable as nitrogen is essential for agromineral formulation.

Table 6 shows that the agromineral application in lateritic soils significantly increased both fruit quantity and total weight (kg) compared to control soil. After 41 harvest days, Puerto Padre variety cucumbers showed improved yields (Figure 5), with earlier harvest times representing an additional productivity benefit.

Figure 5. Development of cucumber cultivation with the application of agrominerals in the Miraflores organoponic.

Tabla 6. Results in cucumber cultivation (Céspedes-Piña, 2023)

Experiments	First Harvest (41 days)		Second Harvest (55 days)		Total	
	Fruits	Weight (kg)	Fruits	Weight (kg)	Fruits	Weight (kg)
Control	25	6	28	9	53	15
Agromineral	33	10	38	12	71	22

3.3. Evaluation of calcilutites in lateritic soils for cucumber cultivation

Heavy rainfall in Moa caused severe flooding in low-lying areas, so early harvest was neccesary. Excessive moisture led to pest outbreaks, particularly in lower bed sections. Interestingly, the bed's final three meters - with highest moisture levels - showed superior fruit size and quantity despite pest damage (Figure 6).

Figure 6. Development of cucumber cultivation at the Moa University organoponic after applying the soil improver and agromineral.

Table 7 compares experimental results between control soil and treated plots, with 4 kg calcilutite applications outperforming 2 kg applications in both fruit count and total weight. These findings demonstrate that carbonate rocks like calcilutites, combined with ammonium-charged zeolitized tuffs, can enhance Puerto Padre cucumber productivity, establishing their potential as soil conditioners and agromineral sources.

Table 7. Results of experiments on cucumber cultivation

Experiments	First Harvest (44 days)		Second Harvest (53 days)		Third Harvest (61 days)		Total	
	Frutos	Peso (kg)	Frutos	Peso (kg)	Frutos	Peso (kg)	Frutos	Peso (kg)
Control sample	24	5,86	21	6,1	6	3,80	51	15,76
Calcilutite (2kg)	38	8,62	42	9,4	12	4,10	92	22,11
Calcilutite (4kg)	56	12,36	54	11,7	16	6,25	126	30,31

3.4. Potential of Agromineral Use in Moa

The utilization of agrominerals formulated with ammonium-charged tuffs presents multiple potential benefits for the Moa region and surrounding areas. Key advantages of this practice include:

- ✓ **Soil fertility enhancement**: Ammonium-charged tuffs provide essential plant nutrients like nitrogen, crucial for plant growth and development. This can significantly improve soil fertility and consequently boost crop productivity in the region.
- ✓ **Improved nutrient absorption efficiency:** Zeolitized tuffs possess the capacity to retain and gradually release nutrients, promoting more efficient nutrient uptake by plants. This leads to better utilization of available soil nutrients.
- ✓ **Environmental pollution reduction**: Ammonium-charged tuff-based agrominerals can help mitigate soil and water contamination by capturing and removing harmful compounds that are currently discharged as aggressive liquid waste.
- ✓ **Agricultural productivity increase**: Through soil fertility improvement, enhanced nutrient absorption, and pollution reduction, these agrominerals could substantially increase agricultural productivity in Moa's low-fertility soils.

4. CONCLUSIONS

- The province possesses diverse materials with agromineral potential based on their chemical and mineralogical characteristics, including vitric and zeolitized tuffs, calcilutites, and ammoniacal waste from nickel industry processes.
- Formulations combining ammonium-charged tuffs and calcilutites prove viable as agricultural agrominerals, as demonstrated by improved yields in bean and Puerto Padre cucumber crops.
- The implemented agrominerals contribute to environmental sustainability by enhancing soil health and reducing pollution from agrochemicals and nickel extraction processes, promoting eco-friendly agricultural practices.

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Additional Information

Conflict of interests

The authors declare that there are not conflicts of interest

Authors´Contributions

LMB, LAPG, and CALR: original idea, literature review, case studies, writing of the manuscript. GCF, GAOM, and ACP: review and composition of the manuscript, approval of the final version.

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