ARTÍCULO ORIGINAL

# Physical and Chemical Characterization of the Organ-Mineral Fertilizer Agromena - G

## Caracterización física y química del abono órgano mineral Agromena - G

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**ABSTRACT:** The unavailability of chemical fertilizers to obtain high yields in Cuban agriculture has led to the development of other organ-mineral fertilizers, such as Agromena - G, produced by the Empresa Geominera del Centro in Villa Clara. The objective of this work was to characterize the organ-mineral fertilizer Agromena - G, based on the determination of the main physical and chemical properties of the fertilizer for its mechanized application in the improvement of soils and the increasing of crops yield. The methodology included the determination of physical properties as granulometry, apparent density and humidity of the organ-mineral fertilizer. In addition, chemical properties such as pH, electrical conductivity, available phosphorus and organic matter were determined. The physical properties of the organ-mineral fertilizer Agromena - G, show that its granulometry (approximately 50% of the grains smaller than 1 mm) favors its use since it facilitates its acquisition by the plants. The other determined properties behave within acceptable values for the most common granular fertilizers. The physical properties of this fertilizer favor its mechanized application both by broadcast fertilizing machines and with machines for localized fertilization. The chemical properties of this organ-mineral fertilizer demonstrated its potential use as an alternative for managing plant nutrition although it is recommended the surveillance of indicators as electrical conductivity and cations concentrations, especially $Na^+$, in clayed soils susceptible to salinity problems.

***Keywords***: Mechanized Fertilizer Application, Granulometry, pH, Available Phosphorus.

**RESUMEN:** La falta de disponibilidad de fertilizantes químicos para obtener altos rendimientos en la agricultura cubana ha motivado el desarrollo de otros abonos órgano-minerales, como el Agromena - G, producido por la Empresa Geominera del Centro en Villa Clara. El objetivo de este trabajo fue caracterizar el abono órgano-mineral Agromena - G, a partir de la determinación de las principales propiedades físicas y químicas del abono para su aplicación mecanizada en el mejoramiento de suelos y aumento del rendimiento de los cultivos. La metodología incluyó la determinación de propiedades físicas como: granulometría, densidad aparente, humedad y ángulo de talud natural. Además, se determinaron propiedades químicas como pH, conductividad eléctrica, fósforo disponible y materia orgánica. Las propiedades físicas del abono organo mineral Agromena - G, muestran que su granulometría (aproximadamente el 50% de los granos menores a 1 mm) favorece su uso ya que facilita su adquisición por las plantas. Las demás propiedades determinadas se comportan dentro de valores aceptables para los fertilizantes granulares más comunes. Las propiedades físicas de este abono favorecen su aplicación mecanizada tanto con máquinas de fertilización a voleo como con máquinas de fertilización localizada. Las propiedades químicas de este abono órgano-mineral demostraron su potencial uso como alternativa para el manejo de la nutrición vegetal aunque se recomienda la vigilancia de indicadores como conductividad eléctrica y concentraciones de cationes, especialmente $Na^+$, en suelos arcillosos susceptibles a problemas de salinidad.

***Palabras clave***: aplicación mecanizada de fertilizante, granulometría, pH, fósforo disponible.

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## INTRODUCTION

In Cuba, the Ministry of Agriculture, according to Decree Law 50 about Conservation, Improvement and Sustainable Management of Soils and the Use of Fertilizers, must demand and control that the users of the soils that carry out agricultural activities guarantee the nutrition of plants for the sustainable use of soil nutrients. In turn, soil users must carry out an integrated fertilization, which includes the use of mineral, organic, organ-mineral and biological fertilizers, correctors, stimulants and amendments to preserve and increase soil fertility (Consejo de Estado República de Cuba, 2021). However, for several years, financial limitations for the purchase of fertilizers and energy for their manufacture have prevented this goal of soil nutrient sustainability from being achieved.

In the national territory, each year in the agricultural campaign, around 827 thousand hectares of crops and about 200 thousand of sugarcane are planted, but only 20% is covered with agrochemicals (Martínez, 2020). This deficit in soil nutrition is one of the causes of the low yields that are obtained in most crops in Cuba. The intensive use of the soil and the non-application of fertilization or soil improvers cause its degradation and the reduction of its production capacity.

Organ-mineral fertilizers have been widely used to improve physical conditions and increase the production capacity of soils. In Cuba, they have been used in crops such as sugarcane, banana, coffee, corn, tomato and other crops (Ochoa *et al*., 2001; Corrales *et al.*, 2011; Cairo *et al.*, 2015; Rodríguez *et al.*, 2015; Cairo et al., 2017; Chaveli *et al*., 2019).

The Research Center for the Mining-Metallurgical Industry (CIPIMM) developed an organ-mineral fertilizer (Agromena) based on the use of organic matter (coal) and minerals such as phosphorus, zeolite, magnesium and others that have had good results in terms of improvement of the physical properties of the soil and the increase in yields of various crops (Velázquez *et al*., 2013).

The physical properties of a fertilizer are of considerable importance, both from the point of view of its agronomic effectiveness and in relation to its satisfactory application, transport and storage conditions. A good number of problems that occur with fertilizers, such as non-uniform application, compaction, segregation and excessive hygroscopicity, are the result of inadequate physical properties (Guerrero, 2004).

The main physical properties of fertilizers are granulometry, apparent density and humidity, among others. (Riquelme & Varas, 2002; Varas y Riquelme, 2002; Guerrero, 2004; Carciochi & Tourn, 2017). Other properties such as pH, organic matter content and electrical conductivity are also important, since they characterize the action carried out by fertilizers on the soil.

The objective of this work was to characterize the organ-mineral fertilizer Agromena - G produced by Empresa Geominera del Centro, for its mechanized application for the improvement of soils and increase of crops yield, based on determination of the main physical and chemical properties of the fertilizer.

## MATERIALS AND METHODS

The research was carried out during year 2022, in the Soil Laboratory of the Agricultural Research Center of the Faculty of Agricultural Sciences at the Central University "Marta Abreu" de las Villas, Villa Clara. The organ-mineral fertilizer used was Agromena - G produced by Geomining Company of the Center.

### Methodology to determine physical properties of organ-mineral fertilizer Agromena - G.

The determined physical properties were granulometry, bulk density, humidity and natural slope angle (NC ISO 5690-1, 2004).

### Methodology for Determination of Granulometry

To determine the granulometry, the material was passed through four sieves of between 1 and 4 mm. These sieves allowed separating the material in the following intervals

- $> 4$ mm
- $> 2$ mm $< 4$ mm
- $> 1$ mm $< 2$ mm
- $< 1$ mm.

### Methodology for the Determination of the Apparent Density and Humidity of the Organ-Mineral Fertilizer

The apparent density was determined as the ratio between the weight of the fertilizer (1g precision scale) and the volume occupied by it (1 cc precision test tube). It was expressed in $kg/m^3$.

The humidity was determined by the gravimetric method, 3 samples of the Agromena - G were taken and were weighed on a 1 g precision balance (wet soil weight), later it was dried in an oven at a temperature of 105 °C, when its weight remained constant was weighed and the weight of the dry soil was obtained. Soil moisture in percent was determined as the weight of water divided by the dry weight and multiplied by 100.

### Methodology for Determination of the Natural Slope Angle

To determine the slope angle, the organ-mineral fertilizer to beused was sieved, later it was placed in the sun to dry and then the Agromena G sample was weighed, it was poured on a flat surface and the height of the cone was measured. The diameter of the base of the cone was marked and its inclined length was measured. This test was repeated three times and the average was taken from the results obtained in order to calculate the angle.

**Methodology to Determine Chemical Properties of Organ-Mineral Fertilizer Agromena - G**

The pH was carried out by the potentiometric method according to the methodology of Hesse (1971) in a soil: water ratio of 1:2.5 (weight: volume). For this, 10 g of air-dried and sieved Agromena to 0.5 mm were weighed. The sieved Agromena was placed in a 50 ml beaker and 25 ml of distilled water for pH in water or 25 ml of 0.1N KCl for pH in KCl were added with a pipette. It was stirred with a glass rod every 15 min for one hour. Finally, it was read in the potentiometer.

For electrical conductivity (EC) 40 g of Agromena were taken, also sieved to 0.5 mm and air-dried. This was placed in a 500 ml Erlenmeyer flask and 200 ml of distilled water were added. The mixture of water and soil was stirred and left to rest overnight (24 hours). The supernatant part was filtered through semi-rapid filter paper; 30 ml of the filtrate were taken and the electrical conductivity was measured in a conductivity meter.

The available phosphorus (P) was extracted by the method of Olsen (Olsen *et al.* 1954); using 0.5 M NaHCO3 as extracting solution at pH 8.5 and for the reducing solution, 0.50 g of $C_6H_8O_6$ are dissolved with ammonium molybdate solution and the same solution is titrated to 100 ml for spectrophotometer reading at 882 nm.

Soil organic matter (SOM) was determined colorimetrically by the method of Walldey and Black (1934).

All chemical analyzes were carried out according to the MINAGRI NRAG 279, (1980).

**Statistical Processing**

To process the results, a database was created in Excel 2013 on Windows 10. The statistical package STATGRAPHIC plus 5.1 was used for data analysis, performing descriptive statistics.

## RESULTS AND DISCUSSION

**Determination of the Physical Properties of the Organ-Mineral Fertilizer Agromena - G.**

***Determination of the Granulometry***

Fertilizers with low water solubility must have a fine particle size to ensure their dissolution in the soil

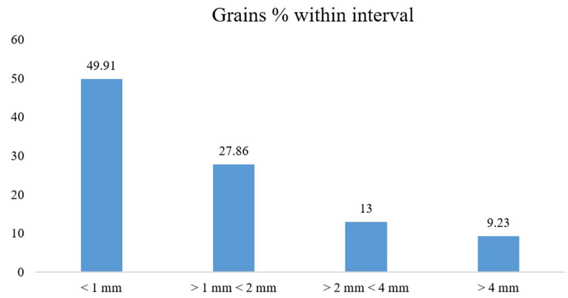


**FIGURE 1.** Grain size distribution in organ-mineral fertilizer Agromena - G.

(Guerrero, 2004; Navarro & Navarro, 2014). Agromena - G, is considered to have low solubility since it is composed of zeolite, phosphorus, other minerals and organic matter, which in some cases do not dissolve in the soil and in others are very slow to dilute. Figure 1 shows the results of the granulometry determination. As it can be seen, 90.77% of the grains are smaller than 4 mm, which is why it is considered to have a fine particle size that facilitates the supply of nutrients to the soil and plants. The effect of the grain size of the fertilizer, on the level of use made by the plants is variable and depends on factors such as the properties of the soil, cultivated species, nature of the fertilizer or manure and technology used for its application.

Guerrero (2004) considers that the fertilizer material is granulated when the particles are made up of granules of variable diameter that generally range between 2 and 4 mm. Agromena - G, according to the results obtained that are observed in Figure 1, cannot be considered as a granular fertilizer, it is considered as a powder one, since almost 50% of the particles have dimensions less than 1 mm. This result is due to the process of obtaining the included minerals, where the particle size is made by grinding, which gives rise to compacted particles of irregular shape and different fineness.

When the fertilizer has a high variation in granulometry and is broadcast by fertilizing machines, segregation or separation by grain size occurs, causing an irregular distribution of nutrients in the field. According to the dimensions of the grain, these are organized within the deposits, as Carciochi &Tourn (2017) assure, most of the smaller particles tend to accumulate in the central and upper part of the storage pile in the warehouse, while the largest particles do so at the base and in the outer part of the pile. The same situation occurs inside the hoppers, due to the vibrations produced during the transport of the fertilizer in bulk.

Segregation is a problem when preparing fertilizers composed by physical mixing of sources with different sizes of grain and, of course, with materials that differ in their chemical composition (Guerrero, 2004), as it is the case of Agromena - G, which is a mixture of minerals and organic matter. However, during the investigation and during the mechanized application of the fertilizer, no segregation of the product was observed.

**Determination of the Apparent Density and Humidity of Organ-Mineral Fertilizer Agromena - G.**

The apparent density of the organ-mineral fertilizer Agromena - G was 1290 kg/m$^3$. This value is somewhat higher than that of granular fertilizers, such as those of the compound type (NP, PK and NPK) that have apparent densities between 900 and 1200 kg/m$^3$ (Guerrero, 2004; Márquez, 2011). The volume of the fertilizer includes the space occupied by the air, between pores. If the fertilizer grains are tighter together, their bulk density will be higher. The higher apparent density in Agromena - G, is due to the process of obtaining the fertilizer, which is by grinding, where a product is obtained in which grains of less than 1 mm (≈ 50%) predominate, which makes this be denser because there is less space between pores. In the case of other materials used as soil amendments and mineral fertilizers, which are also obtained through the same production process, such as phosphoric rock (1360 to 1520 kg/m$^3$) or lime (1 280 to 1520 kg/m$^3$) (Guerrero, 2004), have a bulk density similar to that of Agromena - G.

As Márquez (2011) states, the fertilizer with the lowest apparent density is projected at a shorter distance than the one with the highest density, when it is applied by a machine for the application of broadcast fertilizers, this is not the case when the application is localized. Likewise, the variation of the apparent density of the fertilizer influences the amount (weight) that is applied to the soil, so the appropriate changes will have to be made in the regulation of the machine to ensure the established dose (kg/ha), this consideration is valid for any fertilizer machine.

The gravimetric moisture of the fertilizer was 6.74%, somewhat higher than the proposal of 6% for most nationally produced fertilizers (GEIQ, 2022). The existing moisture in the fertilizer did not cause caking or the formation of lumps, due to its components that are mainly from rocky mineral origin. Excess moisture in the fertilizer is negative, both during storage and during its distribution in the field. Excessive moisture favors the formation of hard-to-break clods that affect distribution.

***Determination of the Natural Slope Angle***

The angle of repose of granular materials is used in the design of equipment for the processing and transporting of granular particles. For example, it is used in the design of grain storage silos or in the design of belt conveyors for granular materials. In the maritime transport of bulk grains it is of importance because it is closely related to the possible shifting of cargo that affects the transversal stability of the vessel.

The natural slope angle or the angle at rest of the material was 32.3°, a value that is close to that of potassium chloride presented by DFGrup (2022) which is 30°. Agromena-G has an intermediate lateral fluidity, ie it flows acceptably according to Dionisi *et al*. (2009), which ensures that with the hopper completely full, the bottom of the hopper always remains full of material, therefore there will be no interruptions in the delivery or unloading of the material.

The main factor affecting the quality of fertilization is the quality of the fertilizer. There is currently no fertilizer machine that can ensure high application quality if the fertilizer is of poor quality. The quality of the fertilizer is given by the uniformity of the particle size, by its dust content, hardness and relative critical humidity. Although there are other characteristics, these are the ones that affect the most (Tourn & Platz 2019).

These characteristics of the fertilizers influence their subsequent handling and the quality of their application, especially when mechanized applications are made. For example, the particle density is a property that affects the effective working width of the application, since the denser particles reach a greater distance and can be applied with a greater speed of rotation of the plates. Other properties such as hygroscopicity and moisture content can affect the quality of its spreading since, as they increase, it becomes more easily moistened and its particles become soft and sticky (Carciochi & Tourn, 2017).

**Chemical Properties of the Organ-Mineral Fertilizer Agromena - G**

According to Minagri (1984) the Agromena - G fertilizer has a slightly alkaline $pH_{(H2O)}$, while its pH (KCl) is in the neutral range (Table 1). This is because zeolites have alkaline cations ($Ca^{2+}$, $Mg^{2+}$, $K^{+}$, $Na^{+}$) in their composition, which influences important properties such as cation exchange capacity (CEC). Furthermore, these minerals have a high affinity for alkaline cations such as ammonium ($NH^{4+}$). This influences these same properties in the soils where it is applied, since these cations are easily exchanged with other ions in the soil solution, such as $H^{+}$ ions, causing the soil pH to rise and show alkaline values (Méndez & Lira, 2019; Torri *et al*., 2021).

Electrical conductivity is an important property since zeolites and their different commercial forms of presentation, such as Agromenas-G, can be used as substrates or applied to the soil as organ-mineral fertilizer. In the case of using it as a substrate, it is considered that electrical conductivity (EC) values, measured in the saturation extract, greater than 3.5 dS

**TABLE 1.** Chemical properties of the fertilizer Agromenas - G

| | pH | | Elect. Cond. | $P_2O_5$ | OM |
|---|---|---|---|---|---|
| | KCl | $H_2O$ | ɥS/cm | mg/100g | % |
| X | 7,12 | 7,66 | 1169 | 12,67 | 5,73 |
| ± SD | 0,03 | 0,08 | 9,54 | 1,33 | 0,25 |

Legend: X indicates mean, SD indicates standard deviation, OM: organic matter

$m^{-1}$ (at 25° C) are excessive for most of the cultivated species. The original salinity of the substrate and its ease to accumulate salts is an important element to consider because they can negatively affect the crop since the response of the plants varies under salinity conditions (Martínez & Roca, 2011).

Márquez *et al.* (2021) characterized the Cuban zeolites from three deposits and classified them as calcium-sodic zeolites since, although their compositions showed variations, $Ca^{2+}$ and $Na^{+}$ cations dominated all of them. In addition, in all cases in the mineralogical composition they found a high content of zeolite phase (61-83%), with clinoptilolite and mordenite predominating in a ratio that oscillates between 0.84 - 4.08. Urbina *et al.* (2006) point out that clinoptilolite contains high levels of $Na^{+}$, which is a phytotoxic element for plants and proposes that it be treated with a solution to exchange this element for other beneficial cations for the crop.

Soca and Daza (2016) found that zeolite applications increased the pH, the contents of exchangeable bases and CEC in three Cuban soils (Grey Brown, Brown with carbonates and Sialitic Humic), which they explain is due to the exchange between $NH^{4+}$ and cations, as $Ca^{2+}$ and $Na^{+}$, with the soil solution, and the consequent release of $OH^{-}$ ions. These authors found that in the Greyish Brown soil the increase in $Mg^{2+}$ was the highest (61%), while in the Brown soil with carbonates the increases in $Ca^{2+}$ and $Na^{+}$ in the soil were higher (16 and 71%, respectively). In addition, they point out that $Na^{+}$ concentrations increased in all soils due to the applications of the zeolitic mineral used, for which reason they recommend periodic evaluations of this element due to its negative effects on the soil structure due to its dispersant properties.

The assimilable phosphorus content can be evaluated as high according to the scale used by Chacon (2014). The Agromenas-G technical sheet characterizes this organ-mineral fertilizer as a source that provides 7% of phosphorus Geominsal (2018), an essential macronutrient for crop development, but whose availability is affected by its low solubility and the complex set of reactions that decrease the concentrations of their forms available to plants.

Torri *et al.* (2021) found that when applying zeolite, the availability of this element decreased as a result of the pH increases in the soil, probably due to the precipitation of these in the form of calcium phosphates and other insoluble compounds. However, there are studies where mixtures of zeolites with phosphoric rock have been used and it has been found that this favors the dissolution of phosphorus from the phosphoric rock and its release into the soil solution with satisfactory results in the yields of crops such as potatoes and sorghum (Soca & Villareal, 2015).

Zheng *et al.* (2022) found that zeolite applications in rice cultivation with alternating irrigation not only increased the availability of phosphorus in the soil, but also influenced the different fractions of this element in the soil and its translocation in the plant with positive effects on the yields of the crop studied. All this implies that, due to the complexity of this nutrient, in terms of its reactions in the soil, studies on the effect of zeolites on its availability must continue to be deepened.

The organic matter content of this fertilizer stands out, which, although it is in the ideal range that soils should have, is below what is stated in the Agromenas-G technical sheet characterizing this organ-mineral fertilizer, in which it is proposed that it contributes 14% organic matter (Geominsal 2018).

The organic matter content is a highly relevant indicator because it significantly influences the properties of the organ-mineral fertilizer. Eifediyi *et al.* (2013) explain that the use of this type of fertilizers has positive effects on the biological activity of soil microorganisms, the formation of aggregates and the availability of nutrients, with the consequent increase in crop yields. Organic compounds promote the release of nutrients and substances that improve soil quality and crop yields, as well as influence the control of phytopathogenic fungi in the soil (Nunes *et al.*, 2013). It should be noted that the contribution of nutrients varies and depends on various factors such as the percentage and quality of the organic matter present, the texture of the soil, the temperature and existing humidity conditions, among other factors (Palma-López *et al.*, 2004; Cairo *et al.*, 2017).

As the organic matter content increases, the total porosity and the hardness of the particles are favored, which is related to the density of the particles and the hygroscopicity and water content of these particles. On the contrary, the apparent density of the fertilizer, the density of the particles and their distribution will decrease when the content of organic matter in the organ-mineral material increases (Paré *et al.*, 2009).

## CONCLUSIONS

The physical properties of the organ-mineral fertilizer Agromena - G, show that its granulometry (approximately 50% of the grains smaller than 1 mm) favors its use since it facilitates its acquisition by the plants. The other determined properties behave within acceptable values for the most common granular fertilizers. The physical properties of this fertilizer favor its mechanized application both by broadcast fertilizing machines and with machines for localized fertilization. The chemical properties of this organ-mineral fertilizer demonstrated its potential use as an alternative for managing plant nutrition although it is recommended the surveillance of indicators as electrical conductivity and cations concentrations, especially $Na^{+}$, in clayed soils susceptible to salinity problems.

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