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PROPERTIES OF GRANULAR ORGANO-MINERAL FERTILIZER AND THE INFLUENCE OF ITS APPLICATION ON SOME CHEMICAL PROPERTIES OF THE SOIL IN AN APPLE PLANTATION, JONATHAN VARIETY

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Abstract

The physical-mechanical properties, as pH and compressive strenght, determined for the fertilizer granules obtained by enriching the compost from urban sludge with mineral fertilizers with N, P, K, fall within the norms imposed on organo-mineral fertilizers. Applying organo-mineral fertilizer to acidic soil in an apple orchard improved the physico-chemical properties of the soil. The experimental factor was the fertilizer dose, placed randomly, in five variants and four repetitions. One year after fertilization, the soil reaction was significantly improved (from pH = 5.4 to pH = 5.80). The mobile phosphorus content in the soil increased significantly in the fertilized variant with 40 t fertilizer / ha. The humified organic matter was at a high level in variant with 60 t/ha (humus = 4,25%) compared to the control variant (humus = 1.58%).

Key words: *biosolid. organo-mineral, fertilizer, properties, soil.*

INTRODUCTION

Due to the nutrient content and the important intake of organic matter, large amounts of sludge can be used in agriculture as fertilizer. The use of sludge in agriculture could solve or alleviate a pressing problem: the removal of residual sludge from wastewater treatment facilities to avoid incineration or other costly and polluting processes (Adugna, 2016; Bowszys et al., 2015; Wei & Liu, 2005).
The application of residual sludge in fruit growing is an inexpensive method and is in line with the ecological principles of waste recycling, and at the same time can be a method of improving the physical, chemical and biological properties of the soil (Aggelides & Londra, 2000). However, its effect apparently depends on pedological conditions and cultivated plant species. In order to minimize the negative effects of residual sludge on a soil, the characteristics of a given sewage sludge and the critical concentrations of heavy metals must be taken into account.
By digesting and stabilizing of raw sewage sludge, in order to reduce the concentrations of pathogens and toxic chemicals below the established levels so that they can be used as fertilizers without harming the health of plants, soil and groundwater, so-called biosolids are obtained (Kominko et al., 2018; Kumar et al., 2017).
Organo-mineral fertilizers obtained by combining organic (biosolids) and mineral fertilizers offer various advantages (Parent et al., 2003; Lee & Bartlett, 1976; Tishkovitch et al., 1983)
The most common presentation form of organo-mineral fertilizers is the granular form which ensures, among other things, the reduction of storage space, the reduction of pollution due to dust and allows precise application (Deeks et al., 2013).
In this paper, the properties of biosolid-based fertilizer granules were determined and the influence on some soil properties of the application of this type of fertilizer was studied.

MATERIALS AND METHODS

The biosolid-based granular fertilizer used for experiments was made by reactive extrusion according to a manufacturing recipe in which the organic part is provided by biosolids, protein hydrolyzate and molasses (Cioica et al, 2020).

The granules are characterized by a water content of 1.33-1.70% and a bulk density of about 850 kg/m^3 (Nagy et al., 2021).

In order to determine the pH of the biosolid based fertilizer, samples of 2 g granules were dissolved in 20 ml of distilled water, after 20 min the pH was measured with pH indicator paper from Merck. Five repetitions were made and the average value was calculated.

The compression tests (Figure 1) were performed for biosolid based granules in initial state and for dried granules with a manual press equipped with a 5 kN force transducer, a Spider 8 data acquisition plate and a mechanical dial indicator, the compression test being videotaped. One granule was used for the measurements, the measurements being repeated 5 times to establish the average value of the compressive strength. The measured values of the granule deformation were taken with a resolution of 0.01 mm in the video recording compression tests. The drying process of the granules was performed with an AXIS 100 thermobalance, at a temperature of 80 ºC until at least 3 consecutive equal values of the mass were obtained.

Figure 1. Compression test

The study regarding the effect of the biosolid based fertilizer on some soil properties was carried out at the Research Institute for Fruit Growing Pitesti, Mărăcineni (44° 51′ 30” N, 24° 52” E), in an apple plantation. The experiment was organized on a wet phreatic aluviosol, formed on fluvial deposits, with a loamy-sandy texture. The field was located in a meadow terrace of the Argeș River. The planting distance of the apple trees is 3.5 m x 1.25 m and the density is 2,285 apple trees/ha.

A single-factor experiment was designed (five experimental variants with four replicates), the experimental factor being the dose, with the following graduations:

V_1 = 0 t/ha (unfertilized control);
V_2 = 20 t/ha;
V_3 = 40 t/ha;
V_4 = 60 t/ha;
V_5 = 80 t/ha.

The five experimental variants were placed randomly, in four replicates.

The biosolid applied in the experimental variants comes from the sludge obtained at the Mioveni wastewater treatment plant. The quality indicators of the biosolid are presented in Table 1.

Table 1. Biosolid quality indicators (Test report, 2018)

No.	Quality Indicators	U. M.	Determined values
1	Dry matter	%	67.86
2	Volatile substance	%	35.34
3	pH measured at 20.6^{0}C	pH units	7.09
4	Nitrogen	% DM	1.52
5	Organic carbon	% DM	21.5
6	P_2O_5	% DM	1.38
7	K_2O	% DM	0.675
8	CaO	% DM	0.35
9	Cadmium	mg/kg DM	1.04
10	Chromium	mg/kg DM	44.8
11	Copper	mg/kg DM	74.3
12	Nickel	mg/kg DM	26.5

Before applying the compost, the soil chemical properties were analyzed using the following methods described by Florea et al. (1987): total nitrogen by Kjeldahl method (Kjeldahl, 1883); extractable phosphorus (P-AL) by Egner - Riem Domingo method (Egnér et al., 1960), by which the phosphates are extracted from the soil sample with a solution of acetate-ammonium lactate at pH=5.75, and determined colorimetric phosphate anion extracted as molybdenum blue (Egner et al., 1960); exchangeable potassium (K-AL) by Egner - Riem Domingo method by which the hydrogen and ammonium ions of the extraction solution replace by exchange the exchangeable potassium ions in the soil sample which are thus passed into the solution (Egnér et al., 1960). Potassium dosing in the solution thus obtained is done by flame emission photometry. Organic carbon is done by- wet oxidation method followed by titrimetric dosing by Walkley – Black with the Gogoasa modification (Edu et al.,2013) and humus (deduced by calculation from organic carbon); soil pH, soil: water ratio = 1: 2.5 by the potentiometric method; mobile aluminum by the Sokolov method (Sokolov, 1939); sum of exchangeable bases and hydrolytic acidity by Kappen method (Soil Survey Laboratory Methods Manual, 1996), base saturation degree (determined by calculation, depending on the sum of bases). Statistical analyses was performed with an IBM SPSS (SPSS 14) software. The results of field estimates and chemical analyzes performed on soil were processed using the variance analysis method and the multiple comparison method. In order to systematize and process the large data volume of analyzes on the physical and chemical characteristics of soil generalizations were made, with the data being presented in tables representing their variations depending on the experiment and agrochemical-agrotechnical measures applied.

RESULTS AND DISCUSSIONS

In general, most cultivated plants prefer soils with a neutral, slightly acidic or slightly alkaline pH (6.3-7.5). At the same time, the consumption of nutrients by plants depends directly on the pH. Calcium and magnesium are easily assimilated by plants at pH 7-8.5, nitrogen at pH 6.0-6.8, phosphorus at 6.5 - 7.5, potassium at higher pH of 6, and the trace elements are assimilated more easily in the acidic environment and more difficult in the alkaline environment. Therefore, any organo-mineral fertilizer must ensure that the pH is kept within optimal limits for plants.
The values of pH, measured for a solution of 20 ml of distilled water and 2 g of biosolids fertilizer, are between 6.5-7.0, with a mean value of 6.75.
The granular form of biosolids based fertilizers contributes to the improvement of their transport, storage and application properties. To ensure these properties it is important to know the compressive strength of these granules.

According to the results obtained in case of granules in the initial state (Figure 2), at a humidity of 1.33-1.70%, a very good concordance of the measured values is observed for three of the five tested samples. The measured values of the granule deformation were taken with a resolution of 0.01 mm in the video recorded compression tests. Thus, the polynomial regression function of third-degree, determined for the 5 measurements, explains in a proportion of 99.63% the behavior of the granules at the compression test. The polynomial equation obtained shows an almost linear behavior of the deformation of the granules in relation to the applied compression force. Regarding the values obtained, the predominantly linear character is observed up to a stress of 150 N in which case the average deformation is about 0.36 mm. Above this value, the polynomial character is observed up to a value of maximum 250 N at which the deformation reached a value of 0.68 mm. Above this value of the compressive force, during the mechanical stress, the granules did not deform anymore.

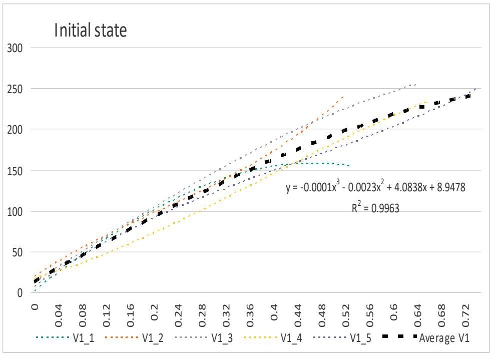

Figure 2. Compressive strength of biosolid based granules- initial state

In case of dry granular material (Figure 3) there is a turning point in the representation of the polynomial regression function of third-degree which explains the behavior of the material in a proportion of 98.5%. The value of this point is found at a force of about 110 N. And in this case there is a very good concordance of the values measured in three of the five tests performed. From the measured values a lower deformation of the granules is observed up to a value of about 80N which corresponds to a deformation of about 0.12 mm, followed by an area of high deformation up to about 125 N corresponding to a deformation of 0.5mm followed again by an area of lower deformation. The maximum value of the force to which the granules deformed was about 200 N at a deformation of 0.68 mm.

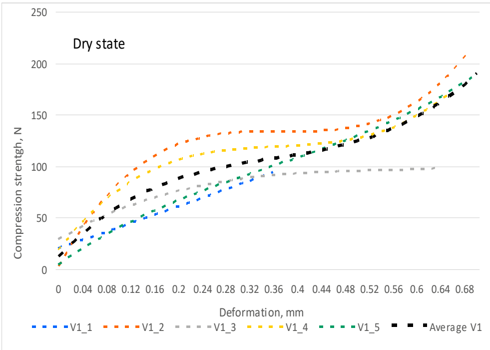

Figure 3. Compressive strength of biosolid based granules - dry state

During the measurements, the deformation of the granules was plastic (Figure 4).

Figure 4. Granules after compression test

The tests show similar deformation for the two humidities of the tested granules, a higher value of the maximum force in the case of dry granules and the influence of humidity in the deformation-stress behavior for the two humidities used.

All these elements lead to the need to extend the tests in order to identify the possibility of using the biosolid based granules for the intended purpose.

The soil properties of the apple plantation, from an agrochemical point of view, falls into the class of acidic soils, with an acidic to strongly acidic reaction, a low-very low humus content in the arable horizon, a very low nitrogen supply, low phosphorus and potassium contents, as can be seen in Table 2.

Table 2. Agrochemical soil properties

Soil depth, (cm)		0-20	20-40
Acidity indicators	pH	5.4	5.2
	Sum of bases SB (me/100 g sol)	14.21	6.0
	Extractable Acidity Ah (me/100 g sol)	2.67	9.7
	Base saturation V (%)	84.19	38.21
	Mobile aluminum Al^{3+} (mg/kg)	11.00	11.81
Fertility indicators	Total nitrogen content N_t (%)	0.08	0.07
	Total phosphorus content P_2O_5-P (mg/kg)	20	18
	Potassium content K_2O-K (mg/kg)	148	130
	Humus content (%)	1.58	1.20

One of the most important factors controlling the immobilization (sorption) and mobility of nutrients in the soil is the pH. Acid soils are characterized by a deficiency of nutrients and toxicity of metals such as Mn, Fe and Al, aluminum being the main limiting factor for plant growth and development in acid soils (Kochian et al., 2004, Gupta et al., 2013).

At a low pH (around 4.3) trivalent aluminum Al^{3+} predominates, which has the greatest impact on plant growth. In contrast, precipitated or chelated aluminum with organic compounds is not toxic to plants (Nogueirol et al., 2015). At a pH higher than 5-6, the dominant species are $Al(OH)_2^+$, $Al(OH)^{+2}$ which are not as toxic as Al^{3+} (Kinraide, 1991, Delhaize and Ryan, 1995, Hagvall et al., 2015, Kisnieriene and Lapeikaite, 2015). Polycationic Al (charge >2) is rhizotoxic as are other polyvalent cations (Kinraide, 1991).

In the case of the soil fertilized with increased doses of biosolid (60-80 t/ha), the high level of aluminum in the biosolid is not found as a high content in the soil, most probably because these are forms of aluminum adsorbed in the structure of the biosolid or in the clay-humic complex (Nicola C., 2021).

From Figure 5 we observe that increasing the dose of biosolid to 40-60 t/ha leads to an increase of the soil pH from 5.4 to 5.8.

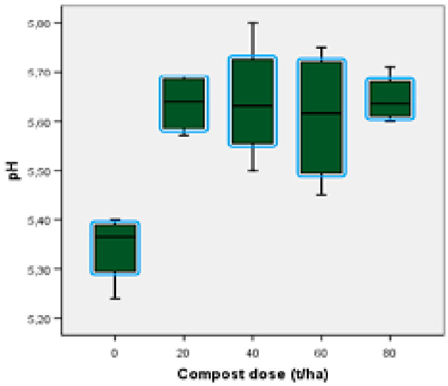

Figure 5. The pH level of the soil

Phosphorus availability is influenced by soil organic matter, pH and Al, Fe, Ca (Smithson, 1999).
Soil reaction pH, Al, Fe, P are properties of the soil related to each other. Their role in plant growth and development is very important. In acid soils the soluble inorganic phosphorus is fixed by aluminum and iron.
Limestone and humus are commonly used amendments to increase soil pH and phosphorus solubility and to suppress the solubility of aluminum and iron in the soil.
Biosolids brings large amounts of calcium into the soil, but also aluminum and iron.
In the 40-60 t/ha biosolid variants, the mobile phosphorus content increased about eight times compared to the unfertilized control, from 25 ppm to 225 ppm (Figure 6).

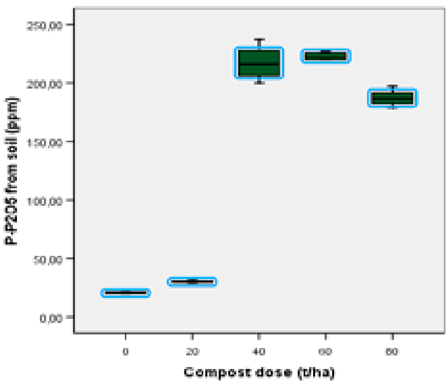

Figure 6. The mobile phosphorus content

Regarding the humus content, it is observed (Figure 7) that a dose of 60 t / ha biosolid ensures an increase of about 2.5 times compared to the unfertilized control.

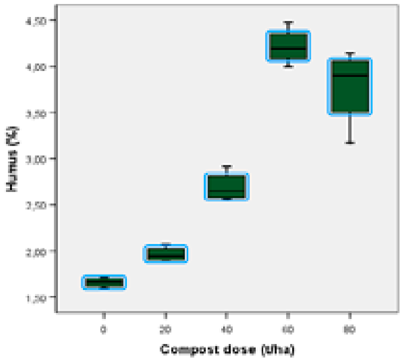

Figure 7. The humus content

CONCLUSIONS

The knowledge of some characteristics of biosolids based granular fertilizers allow the identification of some additives in order to optimize their performances.
The study of the biosolids based granular fertilizers obtained by reactive extrusion showed that the pH obtained of about 6.75 corresponds to the agrotechnical needs.
The values of the compressive strength obtained after the tests, up to 200 N ensure the improvement of their transport, storage and application properties.
The tests show similar deformation for the two humidities of the tested granules, a higher value of the maximum force in the case of dry granules and the influence of humidity in the deformation-stress behavior for the two humidities used.
Experiments have shown that as a consequence of the application of 40-60 t / ha of biosolids the soil pH increased from 5.4 to 5.8., the mobile phosphorus content increased about eight times compared to the unfertilized control and for a dose of 60 t/ha the humus content increase of about 2.5 times compared to the unfertilized control.

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