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EVALUATION OF SOIL QUALITY INDICATORS IN ORGANIC FERTILIZATION AS AN ALTERNATIVE TO SUSTAINABLE AGRICULTURE

SUMMARY

Sustainable agriculture is the yield of agricultural products with good quantity and quality, but with care for the soil in the future. Nowadays, agriculture practices have led to humus reduction in the cultivated soil layer, even in sustainable soils. Applying the principles of the circular economy, composting and organic fertilization are ways to increase the organic matter in the soil. However, whether entirely organic fertilization is an alternative to sustainable agriculture is the aim of this article. The following soil quality indicators are assessed – organic carbon; total nitrogen; ratio C:N. The results present vegetation experience with two scenarios. The first scenario is with Luvisol (LV) and the second is with Fluvisol (FL). Each scenario has an addition of various organic ameliorants. The period of experiment covers the composting period and two vegetation cycles - lettuce and spinach aftereffect. The evaluation is against control variants and limits values. The two soils have different physicochemical characteristics. Luvisol has a higher total carbon content and total nitrogen than Fluvisol. In the end, the 1st soil has increased the SOM up to 4% compared to the second soil, where the improvement is no more than 2%. Accordingly, the nitrogen content is higher in Luvisol than in Fluvisol. In conclusion, we can say that organic fertilization alone is not an alternative to sustainable land management principally because nitrogen depletes after the first growing season in both scenarios of the experiment.

Keywords: manure, composting, organic carbon, total nitrogen, ratio C:N

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INTRODUCTION

Soil organic matter (SOM) is one of the most important soil characteristics. SOM turnover plays a crucial role in soil ecosystem functioning and global warming. SOM is critical for stabilising soil structure, retaining and releasing plant nutrients and maintaining water-holding capacity, thus making it a key indicator not only for agricultural productivity but also for environmental resilience. The decomposition of SOM further releases mineral nutrients, thereby making them available for plant growth while better plant growth and higher productivity contribute to ensuring food security (Van der Wal *et al.,* 2017). Over the last ten years, SOM has been gradually reduced in EU countries. The intensive and continuous exploitation of arable land that can have led to a reduction of organic matter in the soil is reflected in the EU Soil Strategy as one of the most important issues (Atiyeh et al., 2002). Arable land is a source rather than a depot of organic carbon. It's part of SOM which is why some explain as it is the hidden potential (Gougoulias *et al.,* 2014). In Central Europe, the soil organic carbon content is mainly between 3-6%, and in Southern Europe, there are many regions where the soil organic carbon content is 0-2% (FAO, 2017).

The share of the arable area is an important indicator of the impacts of farming on soil organic matter dynamics for it is known that arable areas can deplete soil carbon stocks rapidly (Gobin *et al.,* 2011).

The humus substances in soils are co-concentrated in the one-meter soil layer. Depending on the climate, the microbiological activity and the type of materials transformed into humus, the amount and composition of the soil organic matter for different soils vary widely (Filcheva, 2007). On the territory of Bulgaria, 14 soil groups have been determined. The average content of humus state in the arable horizons in Bulgarian soils is low (Filcheva, 2015).

Preservation of soil organic matter is a potential means of reducing greenhouse gas emissions. The introduction of plant residues, manure, compost and organic sludge in arable land ranks first among the most recommended for maintenance and increase in soils. Applying the principles of the circular economy, composting and organic fertilization are ways to increase the organic matter in the soil. Plant hydrolysates are effective organic fertilizer additives to improve soil fertility. They are a good prospect for the evolution of more efficient methods with application in crop and vegetable production. They are the basis for the production of ecologically clean crops. Compost can be used as a fertilizer in connection with nutrition, but also as an improver of soil texture, and as a microbial additive to increase enzyme activity (Atiyeh *et al.,* 2002; Diacono and Montemurro, 2011; Kaleem Abbasi *et al.,* 2015; Steger *et al.,* 2007). Some authors believe that composts are soil improvers rather than fertilizers, due to the high content of organic matter and lower contents of nitrogen, phosphorus and potassium compared to mineral fertilizers (Khater, 2012). Optimal fertilizer management and efficient nutrient utilization are key to maximizing higher-quality yields (Fageria, 2009; Hariadi *et al.,* 2015). The use of organic fertilizers directly affects the improvement of soil fertility, because it does not increase the content of nutrients directly, but acts as a slow-release fertilizer, providing N, P and K plants more optimally (Purbajanti *et al.,* 2016). However, mature composts increase SOM much better than fresh and immature composts due to their higher level of stable carbon. Nitrogen release in most organic improvers is slow and depends on the processes of mineralization in the soil (C/N ratio), and its absorption by plants affects several physiological processes, and morphological characteristics of yield (Tiemens-Hulscher *et al.,* 2014).

The study aims to determine the effectiveness of organic improvers (organic fertilization) on two soil types by determination of the main components - organic carbon and nitrogen, and the ratio between them for a period covering three of their measurements - composting and two vegetation cycles.

MATERIAL AND METHODS

Experimental Set. The goal was achieved by using the following methodological approach, including: first, the technical stage of mixing the soil with the organic materials for more than 30 days before the Vegetation experiments (VEs) with culture lettuce Lactuca sativa and then spinach aftereffect. VEs contain two scenarios, each with a different soil type. The soils Cinnamon Forest Soil and Alluvial-meadow soil are associated with Chromic Luvisol (LV) and Eutric Fluvisol (FL) by World References Base (WRBSR, 2014). 1st scenario LV has 9th variants vs 2nd scenario FL has 7th variants. They're given below:

Variants 1st scenario

I.1 Luvisol (LV) control
I.2 LV + 5% ready compost *
I.3 LV +10% ready compost
I.4 LV + 15% ready compost
I.5 LV +10% compost, 2 months
I.6 LV + 10% fresh manure (1)
I.7 LV + 10% ready vermicompost
I.8 LV + 10% wastewater treatment plant (WWTP) sludge (2)
I.9 LV + 10% other compost from poultry farm waste
*Ready compost contains components (1) +(2) +straw

Variants 2nd scenario

II.1 Fluvisol (FL) control
II.2 FL + 10% vermicompost
II.3 FL + 10% agro biofertilizer (traditional compost)
II.4 FL + 5% agro biofertilizer (uni granules)
II.5 FL + 10% agro biofertilizer (uni granules)
II.6 FL + 15% agro biofertilizer (uni granules)
II.7 FL + 5% (100 g) dry starting product for agro biofertilizer

Each scenario in VEs contains three repetitions. Two-kilogram vessels were used. Organic improvers are weightily mixed into the soils. Both soil types and organic amendments were examined for many analytical parameters – pH (ISO 10390: 2011), CEC (Ganev and Arsova, 1980), and content of NPK etc. Mainly after the composting period, the changes in the composition and content of SOM, as well as in the supply of nitrogen, phosphorus and potassium were observed. After the two vegetation periods, the yields of lettuce and spinach were followed, as well as some of their quantitative and biometric indicators. This publication shows unpublished data on organic carbon (Filcheva, 2015), total nitrogen (ISO 11261:2005) and their ratio for evaluating organic fertilization efficiency. Data are the average of three measurements and are shown graphically as mean and standard deviation relative to the control variant without organic additive. Data were statistically calculated by descriptive statistics and ANOVA factor analysis.

RESULTS AND DISCUSSION

The figures from 1 up to 3 represent the average change in total organic carbon content, total nitrogen in % and the ratio between them compared to the control variant after a period of composting and two vegetation cycles (on left with Luvisol and on right with Fluvisol).

Changes in the content of organic carbon. The soils have low SOM due to intensive agricultural use. In LV, OC is 1.30% or as SOM 2.24%, in FL, OC - 0.73% or as SOM 1.26%. All input organic materials have the potential to increase the content of SOM in the soil according to the content of total organic carbon, which varies from 8.19 to 20.20%, and the average for all used materials is 15.4 ± 4.1%.

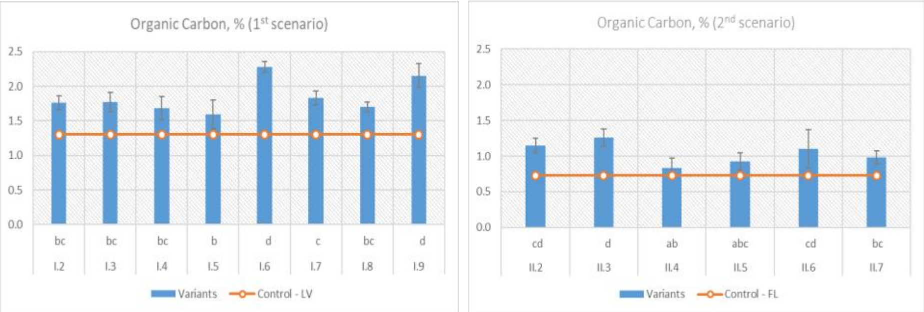

Figure 1. Changes in total organic carbon over the study period in both scenarios

Figure 1 shows that the content of organic carbon is highest when applying fresh manure (I.6) and mature compost from a poultry farm (I.9). For the second soil, it is compost, in the traditional form of Agrofertilizer (II.3). The F-test in the ANOVA show that there is a statistically significant difference between the mean organic carbon from one level of treatment to another at the 95.0% confidence level because P-value of the F-test is less than 0.05.

The increase in organic carbon in the LV was more than in the FL. The increase is from 18 to 70% compared to the control variant for LV and the second soil from 9 to 69%. The change is from medium to high organic carbon for LV and, in the FL, from low to medium. The results correspond very well with the report on the application of organic amendments increases organic carbon by up to 90% compared to unfertilized soil and up to 100% compared to chemical fertilizer treatments (Diacono and Montemurro, 2011). We can say that the best agronomic performance of compost will be at the highest application rates and frequencies

Our published data explain changes in the content and composition of the organic matter of these two soils when adding the organic additives with gradation (5, 10 and 15%), about rates of organic amendments in this experiment. These are variants I.2 to I.4 for LV and II.4 to II.6 for FL. Genetic differences between soils may explain the results of organic carbon change. The main difference between the two soils is the sorption capacity, which shows a different content of colloids in them. Chromic Luvisols contain more colloids than Eutric Fluvisols, respectively 28.3 and 15.6 cmol.kg^{-1}. A good agriculture practice is adding slightly acidic compost to the neutral Eutric Fluvisols (Hristova *et al.*, 2021). In conclusion, our results may put with the connection with carbon sequestration in the agricultural soils of Europe and draw an important decision (Freibauer *et al.*, 2004). It said that efficient carbon sequestration in agricultural soils demands a permanent management change and implementation concepts adjusted to local soil, climate, and management features to allow the selection of areas with high carbon sequestering potential.

Changes in soils by the content of total nitrogen. Input soils have the following supply of total nitrogen: it's medium for LV and low for FL. Organic amendments in 2nd scenario have more nitrogen (2.4±0.4%) compare to the 1st scenario the nitrogen varies from 1.36 in poultry compost (I.9) up to 2,5% in fresh mature and WWTP sludge (variants I.6 and I.8). After applying organic amendments total nitrogen content increased from 33 to 65% in LV and the FL from 24 to 44%. There was no significant increase in option I.5 for LV and option II.5 in FL. The qualitative characteristic for this increase was medium to high total nitrogen in LV and low to medium for FL. There is a good correlation between the total amount of nitrogen in organic materials and their amount in the variants of the two soils.

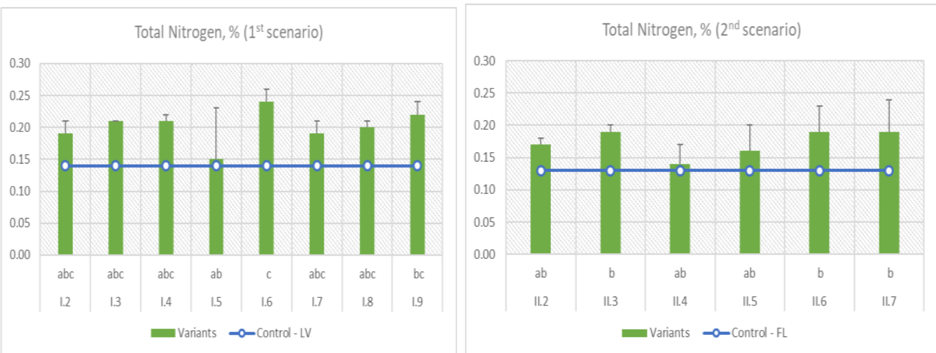

Figure 2. Changes in total nitrogen over the study period in both scenarios

Figure 2 shows the total nitrogen content, the largest amount remaining as a stock after the manure application (I.6) in the first soil type. All variants except 5% uni granules (II.4) are higher in the second soil type than the control. The F-test in the ANOVA shows that there is not a statistically significant difference between the mean total nitrogen from one level of treatment to another at the 95.0% confidence level because the F-ratio is equal to a ratio of the between-group estimate to the within-group estimate.

The assessment of organic fertilization is related to the increase of organic carbon and the main nutrients imported - nitrogen. For example, Flavel *et al.* (2006) found that all amendments released inorganic N at concentrations that would be high enough to warrant a reduction in inorganic N fertilizer application rates. Another author conducted a study with two levels of organic addition: the first low of 33 Mg ha^{-1} to provide the N requirement of a given crop and a high amount of 268 Mg ha^{-1} that maximized the benefit to the soil. The authors demonstrated that the % degradation of organic matter from sewage sludge and cow manure for the first year was 24 and 37, respectively (Tester, 1990).

Within this experiment, there are already published data for both scenarios that have a connection to the nitrogen cycle (Vasileva *et al.*, 2021; Vasileva *et al*., 2022; Hristova *et al*., 2021). The publication on the influence of initial substrates and composts on the growth and yield of Lettuce (Lactuca sativa L.) found that the type of organic enhancer affects growth indicators and yield of lettuce. Maximum yield was reported with the use of vermicompost (I.7) and fresh manure (I.6) (Vasielva *et al*., 2021).

The publication which covered the results of the 2nd scenario of the experiment shows relationships between the application of composts and changes in photosynthetic plastid pigments (Vasielva et al., 2022). The main conclusion is an increase in % Uni Granules has been shown to lead to a higher content of total nitrogen in the soil (R^2=0.988), but no increase in uptake and accumulation of nitrogen in lettuce leaves was observed. On the face of it, there is a significant correlation between the content of nitrogen and chlorophyll in lettuce (R^2=0.965).

In summary of the topic, which covers both variants, it can be said that the experiment is indicative of the development of good agricultural practices because both tested scenarios demonstrated strategic advantages and disadvantages. In the first case, Luvisols and traditional mature are a suitable combination of slightly acidic soil with alkaline organic fertilizer, they fix the organic carbon, but the soil nitrogen isn't enough in the post-vegetation period. In the second case, Fluvisols and granulated mature are the combinations of neutral pH soil with slightly acid granular compost. That scenario positively affects the nitrogen nutrition of plants but does not fix organic carbon very well. This raises working hypotheses to improve the nitrogen supply in the first case and increase the organic carbon in the second case (Hristova *et al.*, 2021).

Changes in soils by the ratio C:N. Figure 3 shows that C:N ratio is proportional to their amount in both scenarios - higher in the first than in the second. Fisher's least significant difference (LSD) procedure shows no statistically significant differences between any pair of means at the 95.0% confidence level.

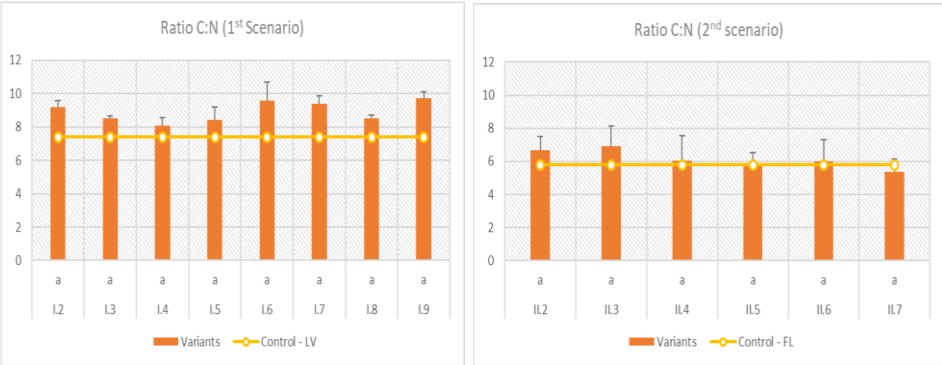

Figure 3. Changes in ratio C:N over the study period in both scenarios

The carbon-to-nitrogen ratio has two aspects in research with organic amendments: agrochemical and soil science. In soil C:N ratio is an indicator of the enrichment of humus with nitrogen. In soil diagnostics, nitrogen enrichment is very high when the ratio value is below 7. In our case, it is the soil in the second scenario because the ratio has a lower rate (Filcheva, 2015).

In our experiment, added different organic additives don't vary by C:N ratio. Organic materials have C:N ratio is 9.4 in traditional mature and 7.2 in granulated mature. Many authors comment that the C:N ratio in organic amendments indicates nitrogen mineralization and there are many outcomes on the kinetics of C and N mineralization by simulated dynamic models (Hadas *et al.* 2004; Lazicki *et al.*, 2020). The models effectively predict N evolution during crop residue decomposition in soil and the conclusion is that higher humification occurred in substrates with lower C:N ratios and we can say that our result covers this hypothesis (Nicolardot *et al.*, 2001).

Ratio C:N is highest in the compost from the poultry farm - variant I.9, and in variant II.2. Higher carbon content and little nitrogen (i.e. very high C:N ratio) variant I.9, in there is no adequate amount of nitrogen, microbes are deprived of their tools to break down carbon compounds or in this variant, the composting process is very it will be delayed. In variant II.2, we have higher nitrogen and low carbon content (i.e. very low C:N ratio). In this case, having more nitrogen than the microbes need to break down the carbon compounds will release more ammonia into the atmosphere.

Important conclusions we found are that applying organic amendments with a C:N ratio of 20 and higher reduced crop biomass and increased soil mineral nitrogen, while amendments with a C:N ratio of 10 had the opposite effect. These results suggest that crop cultivation is suitable for preventing N leaching. Applying organic amendments does not pose a risk of N leaching compared to mineral fertilizers and liquid manure (van der Sloot *et al.*, 2022).

Our research also covers the hypothesis at a C:N ratio of up to 10 and proved that nitrogen is accumulated in plants, but after that supply in the soil is insignificant.

Our conclusion based on this and other experiences (Mitova and Dinev, 2017; Hristova *et al.,* 2018) has relation to published data from an analysis of long-term experiments on the effects of combined application of organic additives and fertilizers on crop yield and soil organic matter comparing outcomes. They demonstrate and we agree with them that adding organic matter (alone or in combination with fertilizers) increases SOM content and their total nutrient management compared to fertilizers applied alone. However, benefits vary between organic and organic + fertilizers depending on the type of land use (Wei *et al.,* 2016).

CONCLUSIONS

The soil evaluation indicators - total carbon, total nitrogen and the ratio between them in the studied two soil types with the application of different additives show a change directly control variants as mean value and standard deviation for the stage including composting and two vegetation cycles. Changes in organic carbon content are statistically proven, while changes in nitrogen content are not. As a result, C:N ratio is not indicative in this case.

The experiment is indicative of the development of good agricultural practices because both tested scenarios demonstrated strategic advantages and disadvantages. These raise working hypotheses to improve the nitrogen supply in the first case and increase the organic carbon in the second case. In conclusion, we can say that organic fertilization alone is not an alternative to sustainable land management principally because nitrogen depletes after the first growing season in both scenarios of the experiment.

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