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THE EFFECTS OF THE APPLICATION OF ORGANIC AND MINERAL FERTILIZERS IN LONG-TERM EXPERIMENTS

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Abstract

The paper presents the results of soil samples obtained from a long-term experience at Livada (Satu Mare County). The experiment carried out was of bifactorial type with variants fertilized with manure and mineral fertilizers with nitrogen and phosphorus. Manure was applied once every 5 years in 4 doses (0 t/ha, 20 t/ha, 40 t/ha and 60 t/ha) and mineral fertilizers in 4 doses (N0P0, N50P0, N50P50, N100P100 kg/ha) annually. The obtained results showed that in the variants fertilized only with manure, the content of mobile potassium increased very significantly for all applied doses, from 162 mg/kg in the control variant to 239 mg/kg in the variant fertilized with 60t/ha. Fertilization with nitrogen and phosphorus determined significant and very significant accumulations of nitrogen, mobile phosphorus, the potassium content having a decreasing trend. The humus content of the soil increased significantly when applying 40 t/ha and 60 t/ha. Productions were reduced in all experimental variants, the year 2022 being a very dry year.

Key words: *organic matter, mineral fertilization, long-term experience.*

INTRODUCTION

The agriculture has to face a large number of challenges imposed by increasing population and diets change, climate change, decreasing resources, geostrategic changes, economic gaps, as well as by the obligation to minimize the impact on the environment as much as possible.

Agricultural production is dependent on environmental resources such as soil, water and air and is vulnerable to climate change, including floods and drought.

Current levels of consumption and production are not sustainable and risk diminishing the planet's ability to provide food for the increasing population. The production and consumption systems must be rethought in order to allow the production of the same amount of products with fewer resources and constantly considering measures to significant and quantifiable improve the quality of the environment.

Soil erosion and contamination, as well as the soil organic matter reduction, reduce its resilience, or its ability to absorb the changes to which it is exposed.

Good nutrient management using a balanced long-term approach is part of a sustainable agricultural system that is resilient to climate and economic change.

Organic nutrient sources are limited and fertilizer preparation requires energy, and recycling nutrients from organic materials and improving nutrient accessibility from well-structured biologically active soils leads to better resource use and economic sense.

The long-term use of chemical fertilizers to increase crop productivity has often negatively affected the complex system of biogeochemical cycles (Perrott et al, 1992; Steinshamn et al., 2004). To increase crop productivity and ensure sustainable agriculture, the use of organic and inorganic sources of nutrients is recommended along with other complementary measures. Organic fertilizers have favorable effects on soil structure and texture and facilitate greater and faster availability of nutrients for plants (Avnimelech, 1986).

The instantaneous assimilation capacity of the soil system is closely related to the ability to aerobically degrade organic matter, thus avoiding problems resulting from septic soil conditions (odors and damage to plants). This capacity is dependent on the state of soil aeration (determined by the texture, structure and moisture of the soil), temperature and organic strength (resistance to mineralization of zootechnical residues). The organic strength of residues is measured in 5-day biological oxygen consumption and/or chemical oxygen consumption, which are appropriate for various residues (Carton and Magette, 1994).

To improve the quality of the soil as well as to increase the yield of crops, an effective way is the application of manure in normal or high doses of amendment, combined with chemical fertilizers (Duan et al., 2011; He et al., 2015; Maltas et al., 2018). However, to date, the response of soil organic carbon stability to fertilization is highly uncertain because the mechanisms controlling its accumulation are not fully understood. Therefore, understanding and characterizing the effect of fertilization on organic carbon accumulation is important for long-term sustainable agriculture management and development (Zhou et. al., 2022).

MATERIALS AND METHODS

The experimental fields were located in the northwestern area of Transylvania, the area that falls within the climatic province Cfbx (according to Köppen), characterized by a moderate temperate-continental climate. The multiannual average temperature recorded at the weather station S.C.D.A. The orchard for 60 years is 9.9°C. In the period 1961-2021, at Livada the multiannual average of the amount of precipitation was 753.2 mm (Figure 1).

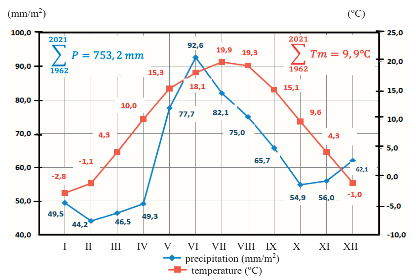

Figure 1. Evolution of monthly multi-annual average of temperatures and mean precipitation sum recorded in the period 1962-2021 at SCDA Livada

In the year 2022, the most severe drought in the history of the existence of these experiences was recorded. Practically in the months of May, June, July, which are decisive for the corn crop, only 65 mm of precipitation was recorded, being much lower than the multiannual average (252.4 mm) (Figure 2).

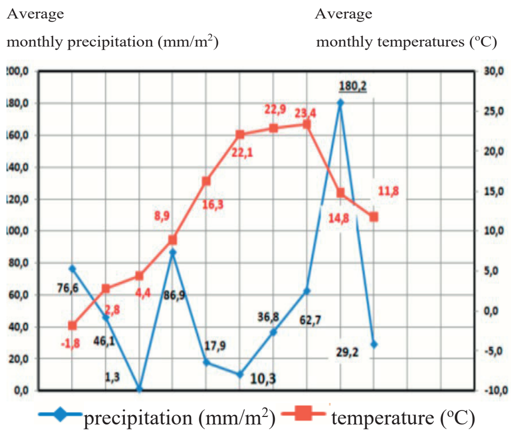

Figure 2. The evolution of average monthly temperatures and precipitation in 2022 recorded at the meteorological station S.C.D.A. Livada

In the same time sequence, precipitation was associated with excessive temperatures. As a result, the productions obtained were the lowest in the last 61 years. The drought period was followed by heavy rainfall that greatly extended the maize growing season.

The stationary experiments with the application of manure and chemical fertilizers (NP) were located in 1967, according to the method of subdivided plots, in a bifactorial manner. The manure was applied once every 5 years in variants of 0, 20, 40, 60 t/ha and annually mineral fertilization with 4 gradations N0P0, N5P0, N50P50 and N100P100 kg/ha. The samples were collected after the maize crop.

Soil samples were collected from the topsoil, at a depth of 0-20 cm, and soil analyzes were performed by the following methods:

- total nitrogen (N%): Kjeldahl method, disintegration with H_2SO_4 at 350°C, potassium sulphate and copper sulphate as catalyst - SR ISO 11261: 2000;
- available phosphorus (mobile): according to the Egner-Riehm-Domingo method and dosed colorimetric with molybdenum blue, according to the Murphy-Riley method (reduction with ascorbic acid);

- total phosphorus, colorimetric method. ICPA Methodology 1986, chap. 8, point 2, PT 2.

RESULTS AND DISCUSSIONS

Production - The data presented in Figures 3, 4 and 5 highlight a very low level and a high variability of productions under the influence of the accentuated drought from the year 2022. Figure 1 highlights the increase of productions under the influence of mineral fertilization. The highest level of production, significantly different from the unfertilized control variant, was obtained following the administration of the highest dose ($N_{100}P_{100}$). The contribution of phosphorus to the increase in production can be observed, which can be attributed to the fact that it is required especially in the first phases of vegetation when it has a significant influence on the growth of the root system, therefore also on resistance to drought and diseases.

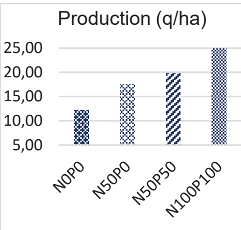

Figure 3. The influence of NP fertilization on production

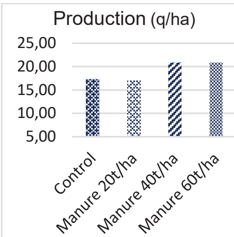

Figure 4. The influence of manure fertilization on production

Although administered only once every 5 years, manure fertilization is useful because it ensures less variability of productions due to decomposition over time and longer-term provision of the nutrients needed by the plants, increases the plants' resistance to drought, provides an intake of organic matter in the soil, with all the advantages it offers. Organic fertilization with cattle manure, with doses of 20-60 t/ha, did not ensure statistically guaranteed increases in the corn crop in 2022 (Figure 4). Statistically assured production increases are only achieved in years 1 and 2 of administration.

Figure 5 shows the results that highlight the impact of organic and mineral fertilization on production. The data show significant yield increases over N_0P_0 where doses of $N_{50}P_{50}$ or $N_{100}P_{100}$ + 40-60 t/ha manure were applied.

The results obtained require the recommendation to increase the doses of fertilizers applied above the level of $N_{100}P_{100}$ and to apply organic fertilizers every year at least once every 2 years.

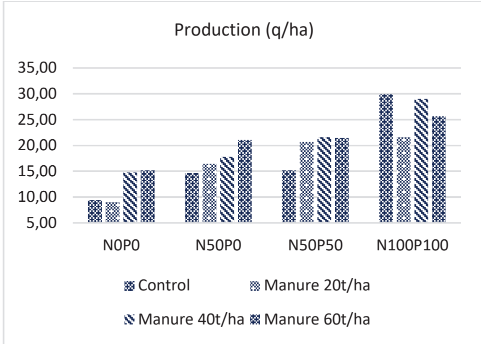

Figure 5. The influence of NP and manure fertilization on production

pH evolution - one of the most extensive soil degradation processes at SCDA Livada is acidification, which covers over 60-65% of the area. This process has increased in the last 50 years, on the one hand as a result of industrial development (acid rain, deposits with acid reaction), and on the other hand as a result of the large-scale use of fertilizers with physiological acid reaction (Henzsel et al., 2012).

The pH values determined after 55 years are presented in Figures 6, 7, 8. Analyzing the evolution of the obtained values, it was found that the most pronounced acidification was generated by the application of nitrogen in doses of 50 kg/ha on a background of P0 and $N_{100}P_{100}$, doses at which soil acidification was very significant from a value of 5.90 in the unfertilized control to 5.43 in the N50P0 variant, respectively 5.13 for $N_{100}P_{100}$, values to which the application of amendments is required. When $N_{50}P_{50}$ doses were applied, the growth was significant, the phosphorus intake stimulated plan.

The application of manure contributed considerably to the fading of the acidity generated by mineral fertilization, achieving a slight increase from 5.41 in the control variant to 5.54 when applying 60 t/ha of manure, a fact that recommends mineral fertilization together with the organic one even once every 5 years.

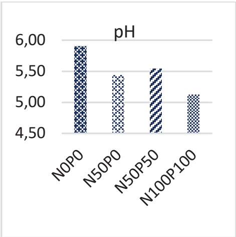

Figure 6. The influence of NP fertilization upon soil pH

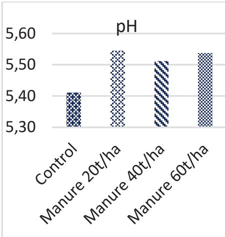

Figure 7. The influence of manure fertilization upon soil pH

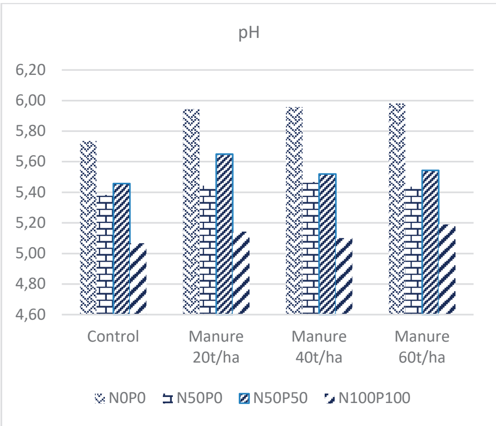

Figure 8. The influence of NP and manure fertilization upon soil pH

Humus - intensive agriculture causes land degradation and other environmental problems, such as: pollution, soil erosion, loss of fertility, decrease in biodiversity and greenhouse gas emissions, which exacerbate climate change (Francaviglia et al., 2023).

Humus is considered to be a sensitive indicator of assessing the effects of different agricultural practices on soil fertility and the soil organic carbon pool (Jin et al., 2023).

Soil organic carbon plays an important role in soil nutrient supply, energy flow and material transformation (Wu et al., 2023). Some previous studies suggested that long-term application of organic fertilizers alone (Wei et al., 2016) or combined with inorganic fertilizers (Su et al., 2006) can significantly increase organic carbon content in large aggregates; for example, Zhang et al. (2019) found that organic carbon was significantly fixed at 0.25–2 mm aggregates; Zhang et al. (2017) found that organic carbon content in aggregates >2 mm increased significantly. However, some studies suggested that inside the microaggregates the content was higher (Huang et al., 2010); for example, Zhang et al. (2018) found that in aggregate of 0.01-0.1 mm, the organic carbon content of the total aggregates is exceeded by 50%.

Soil aggregates are the most basic structural units and are important components of soil. About 90% of organic carbon on the soil surface is fixed in aggregates, and the "hierarchical structure" between aggregates of different particle sizes leads to the transformation of soil matter and energy, which promotes nutrient cycling and soil supply (Su et al., 2006).

Isolation and quantification of soil organic matter pools under the influence of management practices is necessary to assess changes in soil fertility, long-term manure + inorganic fertilization is crucial for improving C and N sequestration by changing the size and response of soil organic matter pools (Mustafa, et al., 2022). Guo et al. (2017) found that long-term addition of nitrogen (126-252 kg·ha^{-1}) and phosphorus (140-280 kg·ha^{-1}) significantly reduced mineralization rate and cumulative C fluxes by increasing the aromaticity of organic carbon substrates.

The results obtained in the experimental variants presented in Figures 9, 10, 11, demonstrated that the application of mineral fertilizers with nitrogen and phosphorus significantly and very significantly increased the humus content of the soil from 1.38% in the control variant to 1.61% in application of N100P100. For the variants of N50P0 and N50P50 the humus value was approximately equal, which means that the phosphorus input of 50kg/ha did not influence the humus content of the soil.

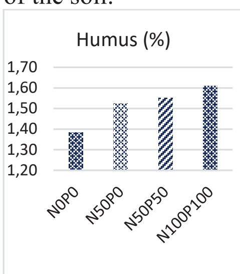

Figure 9. The influence of NP fertilization upon humus content

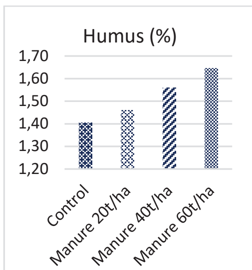

Figure 10. The influence of manure fertilization upon humus content

Although small doses of mineral fertilizers were applied, they were sufficient to achieve the low productions caused by the drought which diminished the process of mineralization of organic matter in the soil. The fact that the soil samples were collected in the fifth year after the application of manure, at doses of 20t/ha, its effect was insignificant. The application of 40 and 60 t/ha even in the fifth year increased the humus content of the soil very significantly (by 11.1% when applying 40t/ha and by 17.2% at 60 t/ha).

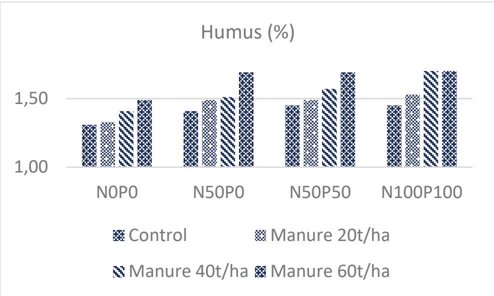

Figure 11. The influence of NP and manure fertilization upon humus content

Nitrogen - Among the nutrients, nitrogen has the greatest effect on plant growth, production and production quality. Appropriate nitrogen management is required because excess nitrogen leads to reduced yields, financial losses, delays ripening, reduces resistance to fall and drought, increases sensitivity to diseases and pests, changes the ratio between straw and grain, reduces storage resistance, etc. The utilization of manure requires controlling the moment of application, knowing the nitrogen load, reducing losses through ammonium volatilization, denitrification and washing, increasing the degree of utilization of the contained nutrients.

Nitrogen is a major driver of N_2O emissions, but also the limiting nutrient for crop production and yield (Linquist et al., 2012). 70% of the global N_2O emission comes from the processes of nitrification (conversion of ammonium into nitrate) – denitrification (conversion of NO_3^- into atmospheric dinitrogen) (Ussiri, 2013).

In order to reduce nitrogen losses, it is necessary to apply doses of fertilizers in accordance with the requirements of the plants, the reserve in the soil, the preceding plant, the time and method of application. The effect of different doses of nitrogen on production and soil characteristics will be researched.

The results obtained in the long-term experiment (Figures 12, 13, 14) demonstrated a significant increase in the total nitrogen content in the soil from 0.096% in the unfertilized version to 0.104% in the versions in which doses of 50 kg N/ha.

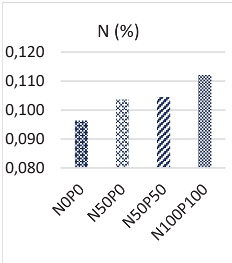

Figure 12. The influence of NP fertilization upon nitrogen content

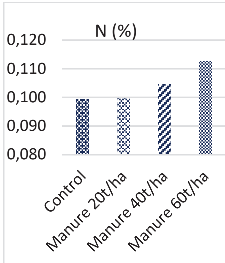

Figure 13. The influence of manure fertilization upon nitrogen content

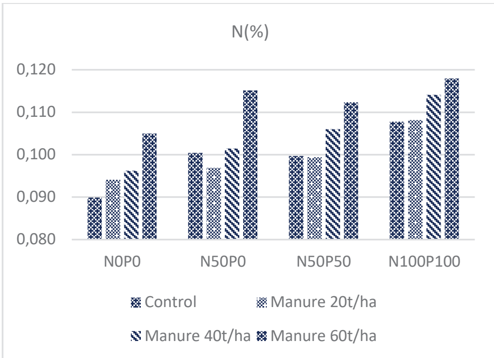

Figure 14. The influence of NP and manure fertilization upon nitrogen content

The application of phosphorus did not cause changes in the total nitrogen content, a fact also demonstrated by the results obtained at SCDA Teleorman after 39 years of experience (Mărin & Negrilă, 2022). When applying N100P100, the soil nitrogen concentration increased significantly from 0.096% in the unfertilized version to 0.112%. This increase in the nitrogen content of the soil can be largely due to the deficient rainfall regime that determined small agricultural productions, therefore a reduced consumption of nutrients, but also a decrease in losses through leaching on the soil profile. In the fifth year after application, the manure brought an input of 5.03% at doses of 40t/ha and 13.2% of nitrogen in the soil at doses of 60t/ha.

Phosphorus - Globally, phosphate rock reserves are decreasing, while the amount of P-containing organic waste is constantly increasing. The use of such biowastes as organic amendments in agriculture is the ultimate disposal goal of environmental and agricultural agencies worldwide (Baram et al., 2023).

In soil, phosphorus comes from the parent rock on which the soil formed and evolved. Sedimentary rocks contain 0.05-0.3% P_2O_5, crystalline ones 0.2-0.7% P_2O_5, and igneous ones 0.3-1% P_2O5 (Sala, 2007). Of the total phosphorus content of the soil, only 0.5-1% is accessible to plants, its mobility in the soil being low. In soil organic matter, the C: N: P ratio is 100: 10: 1. If the C: N ratio is 200: 1 or lower, then the mineralization of organic matter and the replenishment of the soil solution with phosphate ions occurs, and if the ratio is 300:1 or higher, the insolubilization of phosphorus occurs (Mărin et al., 2022) .

Analyzing the results from the long-term experience presented in Figures 15, 16, 17, it is found that the application of phosphorus fertilizers contributed to very significant increases in mobile phosphorus in the soil (from 20 mg/kg P in the control variant to 62 mg/kg P when applying 50 kg P/ha, respectively 120 mg/kg P when applying doses of 100 kg P/ha. As with nitrogen, drought conditions and low production led to accumulations of this element in the soil. Manure did not generated statistically guaranteed increases in mobile phosphorus in the soil.

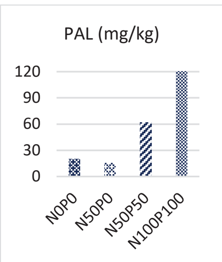

Figure 15. The influence of NP fertilization upon phosphorus content

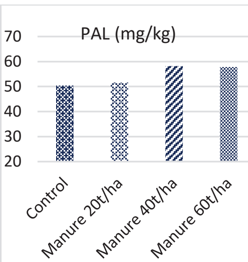

Figure 16. The influence of manure fertilization upon phosphorus content

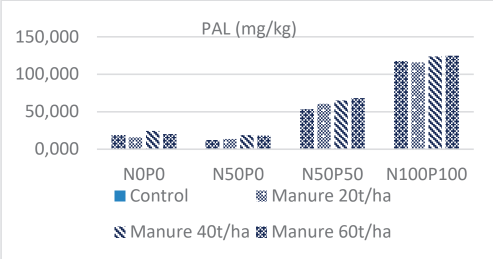

Figure 17. The influence of NP and manure fertilization upon phosphorus content

Excessive uptake of phosphorus (P) by maize can lead to a decrease in grain yield. P uptake indirectly influences the uptake of other nutrients and their translocation within the plant. Consumption of luxury P beyond the point corresponding to maximum grain yield significantly decreases N, S, Fe, Cu and Zn (Penn, et. al., 2023).

Potassium - in the variants fertilized with NP, a decrease in the mobile potassium in the soil was found, not statistically guaranteed, very significant increases were determined when the manure was added to all three applied doses (Figures 18, 19, 20).

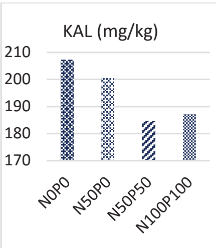

Figure 18. The influence of NP fertilization upon potassium content

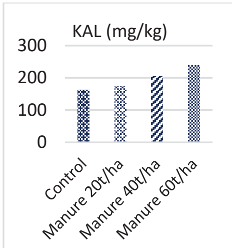

Figure 19. The influence of manure fertilization upon potassium content

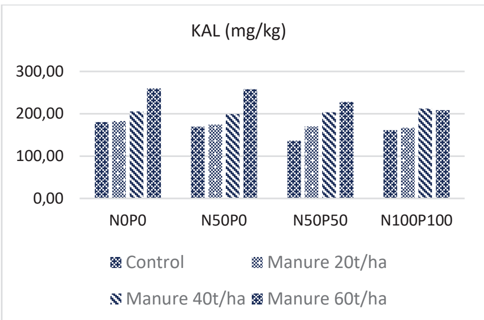

Figure 20. The influence of NP and manure fertilization upon potassium content

CONCLUSIONS

Although the year was very dry, fertilization with high doses of nitrogen and phosphorus brought the biggest increases in production.

Long-term fertilization with nitrogen ensures an increase in the nitrogen content of the soil both at doses of 100 kg N/ha and 50 kg N/ha, accumulations to which the very low amount of precipitation and implicitly low production also contributed, but it causes an acidification pronounced soil, it is recommended to apply calcareous amendments.

Manure has an important role in the supply of nutrients to the soil, and through the buffering effect it contributes to the fading of soil acidity generated by mineral fertilization with nitrogen. The application of 40 and 60 t/ha even in the fifth year increased the humus content of the soil very significantly, the application of 20 t/ha of manure after 5 years had insignificant effects on the production and fertility of the soil.

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