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Effects of fermented chicken manure products on the N mineralization rate of the soil using the incubation method

Florence Alexandra Tóth* – János Tamás – Péter Tamás Nagy

University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental Management,
Institute of Water and Environmental Management, Böszörményi str. 138, Debrecen, Hungary
*Correspondence: toth.florence@agr.unideb.hu

SUMMARY

In our study, the effect of fermented and specially added poultry manure products (superabsorbent polymer (SAP), bentonite and Aegis as a mycorrhizal inoculum) were investigated in a short soil incubation experiment – at 60% water capacity level - on sandy soil. Soil samples were collected from two layers of the incubation pots after the second and fourth week to check the status of the tested products and the processes in the soil. The pH and the electric conductivity (EC) of the samples were measured using an electrochemical method, while the ammonium and nitrate content of the samples was determined with a photometric method. Soil pH and EC values slightly were decreased during the experiment. Our results pointed out that the increasing dose of SAP caused lower soil pH. The nitrate content of the soil did not change significantly during the experiment. It was found that the increasing SAP content in the products, due to its cross-linked structural property, protected the nitrate ions from leaching. Our results suggest that applied SAP does not bind the nutrient ions so tightly in its structure that it competes with the plant for uptake.

Keywords: *soil incubation, organic fertilizer; chicken manure, product development*

INTRODUCTION

Practitioners of sustainable agriculture seek and integrate different methods into their work. Growers may use these methods to promote soil health, minimize water use, and lower pollution levels on the farm.

Sustainable soil nutrient management (SSNM) is defined as managing the application of commercial fertilizers, manure, amendments, and organic by-products to agricultural landscapes as a source of plant nutrients. Two overall objectives in SSNM are to improve soil health and to meet the nutrient requirements of crops. Understanding the soil nutrient changing processes in the soil is key in this respect.

Unfortunately, several Hungarian soils are lack of soil organic matter. Therefore, adequate organic matter supply is necessary for SSNM and healthy food production.

Moreover, the last three decades have seen a large increase in the production of waste, mainly from agricultural activities, which can be recycled as a source of plant nutrients and used to improve soil quality. The use of these materials could partially offset the need for mineral fertilizers, with economic and environmental benefits and in line with the objectives and aims of greening programs (Cordovil et al., 2005; EU New CAP 2021). The ‘green direct payment’ (or ‘greening’) supports farmers who adopt or maintain farming practices that contribute to EU environmental and climate goals (European Green Deal). In this respect, the use of animal manure is a great possibility to achieve these aims. Chicken manure is considered to be an excellent source of nutrients, as it is very high in nitrogen and contains high levels of potassium and phosphorus. In addition, manure production is expected to increase in the coming decades as the growing human population and changes in dietary patterns lead to an increasing demand for livestock and consumption of more meat (Herrero and Thornton, 2013; Dixon 2020; Rayner et al., 2020). Chicken manure alone does not provide adequate nutrient supply. Therefore, it is important to complement its effects with materials that meet the today’s challenges, i.e. problems caused by diminishing water supplies, hectic rainfall patterns and nutrient leaching.

In recent years, there has been renewed interest in applying water superabsorbent materials for alleviation of certain agricultural problems (Buchholz, 1994; Buchholz and Graham, 1998; Abd EI-Rehirn et al., 2004).

They have been successfully used as soil amendments in the horticulture industry to improve the physical properties of the soil in terms of increasing their water-holding capacity and/or nutrient retention of sandy soil to be comparable to silty clay or loam. Superabsorbent hydrogels potentially influence soil permeability, density, structure, texture, evaporation, and infiltration rates of water through the soils. The hydrogels reduce irrigation frequency and compaction tendency, stop erosion and water runoff, and increase the soil aeration and microbial activity (Flannery and Busscher, 1982; Abd EI-Rehirn et al., 2004; Burke et al., 2010). The hydrogels also act as a slow release system by favouring the uptake of some nutrient elements, holding them tightly, and delaying their dissolution. Consequently, the plant can still access some of the fertilizers, resulting in improved growth and performance rates (Ahmed, 1990).

To check these effects, a soil incubation experiment was set up to monitor the nutrient transformation processes in the soil. Soil incubation method is widely used in agricultural studies.

Soil incubation, a biological method, is an excellent way of testing and estimating the nitrogen supply capacity of soils (Stanford, 1972). The aim of soil

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incubation, is to obtain more accurate information on the amount of the availability of nitrogen for the plants from the soil organic matter content during the growing season. It consists of maturing the soil at a predetermined moisture content and temperature for a predetermined period of time and measuring the amount of mineral nitrogen produced during this time.

The main aim of this study to investigate the effects of some new prototype products on soil parameters in an incubation experiment.

MATERIALS AND METHODS

To study the effects of produced prototype fertilizer on soil parameters, an incubation experiment was made. Laboratory measurements were performed at the University of Debrecen, Water and Environmental Management Institute, Organic Material Research Center. The experiments were continued for one month. Soil samples were collected from the Pallag Experimental Station area of Institute of Horticultural Science of University of Debrecen, in Hungary. Soil parameters were measured in the Agrarian Instrument Centre according to Hungarian standards (MSZ 20135:1999). The characteristics of the soil used in the incubation experiment are showed in *Table 1*.

Pallag soil type was brown forest soil with sandy texture and alternated layer of clay. Soil pH is slightly acidic without carbonate and water soluble salt content. N and K supply of the soil is low, but the P supply of the soil is good for plant nutrition. Excessive Mg were measured in the soil. The soil is relatively poor in micronutrients due to the soil type.

Bio-Fer product (Natur extra (NEX)), as raw material was used in the trial, produced by Baromfi Coop Ltd. The parameters of NEX can be seen in *Table 2*.

Table 1: **The basic parameters in Pallag Experimental Station**

Basic soil parameters	Value	Basic soil parameters	Value
pH (KCl)	6.07	Sodium (mg kg^{-1}) (AL)	25.90
Plasticity index (K_A)	<25.00	Magnesium (mg kg^{-1}) (KCl)	136.00
Water soluble salts (w/w%)	<0.02	Sulphur (mg kg^{-1}) (KCl)	3.66
Carbonate (w/w%)	<0.10	Manganese (mg kg^{-1}) (EDTA)	28.80
Org. C (w/w%)	0.89	Zinc (mg kg^{-1}) (EDTA)	0.72
Phosphor pentoxide (mg kg^{-1}) (AL)	135.00	Copper (mg kg^{-1}) (EDTA)	0.60
Potassium-oxide (mg kg^{-1}) (AL)	101.00	Organic Nitrogen (w/w%)	0.07
Nitrate (mg kg^{-1}) (KCl)	11.60		

Table 2: **Main characteristics of Bio-Fer Natur Extra product**

Components	Value	Components	Value
Nitrogen (w/w%)	5.50	Mn (mg kg^{-1})	374.00
Phosphorus (P_2O_5) (w/w%)	3.00	Mo (mg kg^{-1})	3.66
Potassium (K_2O) (w/w%)	2.50	Zn (mg kg^{-1})	367.00
Ca (w/w %)	6.00	Cu (mg kg^{-1})	53.30
Mg (w/w %)	0.50	Moisture content (w/w%)	12.00
S (w/w %)	1.00	pH	7.20
B (mg kg^{-1})	31.40	Total organic carbon (w/w%)	73.00
Fe (mg kg^{-1})	545.00		

Source: https://bio-fer.hu/bio-fer-natur-extra/

In the experiment, three different amendments were used: superabsorbent polymer (SAP), bentonite and Aegis to improve the properties of chicken manure product.

Stockosorb was used as a SAP, which is a cross-linked copolymer, contains acrylamide and potassium polyacrylate (EVONIK Nutrition & Care GmbH). Bentonite is a clay generated frequently from the alteration of volcanic ash, consisting predominantly of smectite minerals, usually montmorillonite. It could be used as a natural soil amelioration, keep substantial amount water and nutrients, decrease evaporation and expand topsoil infiltration by building soil features/agglomeration (Mi et al., 2020). Aegis mycorrhizal inoculum (Italpollina SPA) contains Aegis associates *Glomus intraradices* (25 spores g^{-1}), *Glomus mosseae* (25 spores g^{-1}), Rhizosphere Bacteria ($1x10^7$ UFC g^{-1}) to ensure the persistence of mycorrhizal symbiosis for the entire crop cycle. It increases harvest and plants resistance against abiotic stress (Agnolucci et al., 2019).

NEX, bentonite, SAP and Aegis were mixed and capsulated in a cellulose capsule. Every capsule contains 0.5 g mixture. 200 gr soil was put in small plastic pots for incubation. Capsules were placed at a depth of 2 cm in the soil. One capsule was put in every pots. Samples were incubated for a month at room temperature, at 60% water capacity level. Distilled

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water was used to adjust the water capacity level of the soil. In the experiment, a short incubation period was used to determine the effect of the used capsule form on nutrient uptake.

Six treatments with three replications were applied in this incubation experiment (*Table 3*). NEX, SAP and bentonite ratio was showed in the *Table 3.* The amount of NEX and Aegis were constant (90 and 0.4 w/w %) in all capsules while the amount of SAP was varied between 0.5 to 2.0 w/w % and the bentonite between 8.0 to 9.5 w/w %. Control treatment contained NEX only (Control NEX) while NEX and Aegis were used in Control NEX A treatment.

Soil samples were collected from two layers after the 2nd and the 4th weeks. The upper layer was the upper 5 cm of soil surrounding the capsule. The deeper layer was the lower 5 cm of soil, under the capsule, the bottom of the pot. Treatment codes were showed in *Table 4*.

Table 3: **Applied treatments in the trial**

Treatments	Treatments
Control NEX	90.0 : 1.0 :9.0 ratio
Control NEX A	90.0 : 1.5 :8.5 ratio
90.0 : 0.5 :9.5 ratio	90.0 : 2.0 :8.0 ratio

Soil pH and electrical conductivity (EC) were measured by electrochemical method (WTW pH/cond 3320 SET2). The inorganic nitrogen forms (nitrate and ammonium) were measured by photometric methods (PF 12 spectrofotometer). For soil analysis two extracants were used. The pH and the EC were measured from water extracant and nitrate and ammonium contents were determined from 1M KCl extracant according to the Hungarian standard (MSZ 20135:1999).

Table 4: **Legends for boxplot figures**

Treatment	Treatment
A – Control NEX deeper layer	B – Control NEX upper layer
C – Control NEX A deeper layer	D – Control NEX A upper layer
E – 90.0 : 0.5 : 9.5 ratio deeper layer	F – 90.0 : 0.5 : 9.5 ratio upper layer
G – 90.0 : 1.0 : 9.0 ratio deeper layer	H – 90.0 : 1.0 : 9.0 ratio upper layer
I – 90.0 : 1.5 : 8.5 ratio deeper layer	J – 90.0 : 1.5 : 8.5 ratio upper layer
K – 90.0 : 2.0 : 8.0 ratio deeper layer	L – 90.0 : 2.0 : 8.0 ratio upper layer

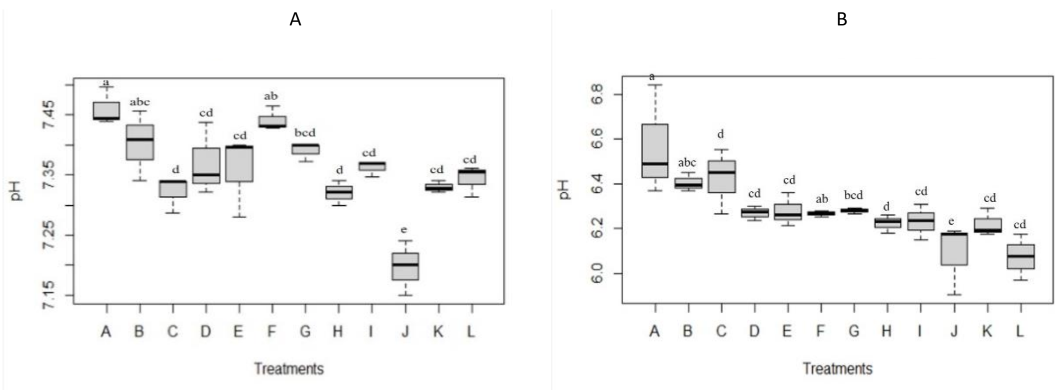
Statistical analysis

Statistical analyses were performed using R software in an R Studio user environment (version 4.0.3.). The Shapiro–Wilk normality test was used to examine the distribution of the data, and then the type of test to be used for further analyzes was selected as a function of the distribution. To verify statistical differences between the different treatments, one-way analysis (Duncan-test, Kruskal – Wallis test) of variance was used at a $p < 0.05$ level of significance.

RESULTS AND DISCUSSION

Effect of treatments on soil pH after 2nd and 4th week were showed in *Figure 1AB*. The pH values are varied between 7.2 and 7.45 after the 2nd week and 6.1 and 6.5 after the 4th week. Soil pH values slightly were decreased during the experiment. All applied treatments slightly decreased soil pH value in the experiment. This effect was significant in many treatments. Our results pointed out that the increasing dose of SAP caused lower soil pH.

Figure 1AB: **Effect of treatments on soil pH after 2nd (A) and 4th (B) week**



In each box plot, means followed by the same letter are not significantly different (P<0.05).

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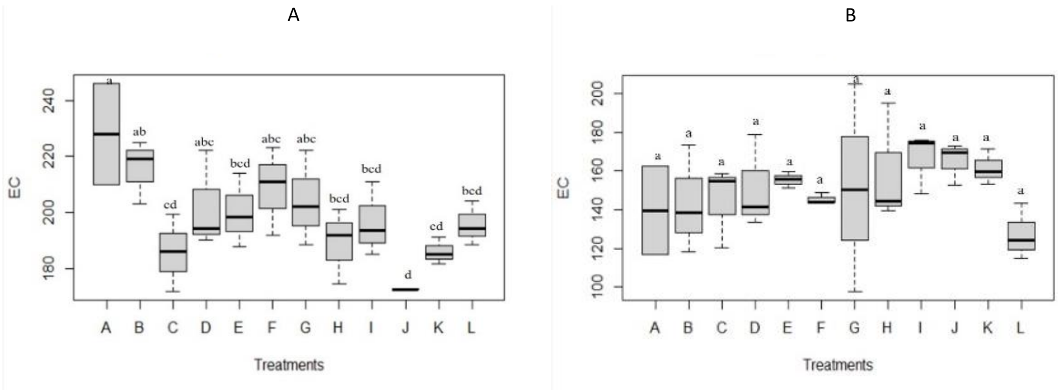
Effect of treatments on soil EC after 2nd and 4th week were showed in *Figure 2AB*. The measured EC values are varied between 180 mS cm^{-1} and 230 mS cm^{-1} after the 2nd week and 130 mS cm^{-1} and 170 mS cm^{-1} after the 4th week. EC values were slightly decreased during the experiment, in all treatments. This tendency was similar to those obtained at soil pH. Moreover, soil EC was not affected by the treatments significantly.

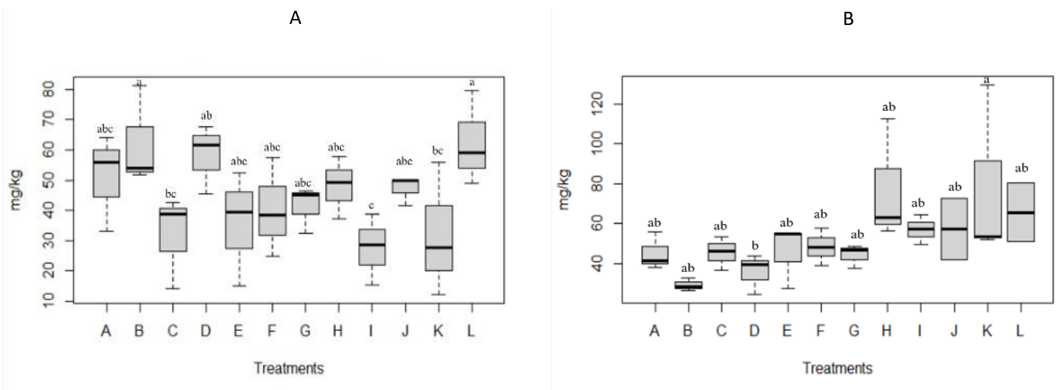
Figure 2AB: **Effect of treatments on soil EC after 2nd (A) and 4th (B) week**



In each box plot, means followed by the same letter are not significantly different (P<0.05).

Effect of treatments on soil nitrate content after 2nd and 4th week were showed in *Figure 3AB*. The nitrate content values are varied between 25 mg kg^{-1} and 65 mg kg^{-1} after the 2nd week and 20 mg kg^{-1} and 60 mg kg^{-1} after the 4th week. The nitrate content of the soil did not change during the experiment regardless of the treatments. Soil nitrate contents in the control treatment showed more significant leaching tendency than in the applied treatments at the end of the experiment.

Figure 3AB: **Effect of treatments on soil nitrate content after 2nd (A) and 4th (B) week**



In each box plot, means followed by the same letter are not significantly different (P<0.05).

Effect of treatments on soil ammonium content after 2nd and 4th week were showed in *Figure 4AB*. The soil ammonium content values are varied between 11 mg kg^{-1} and 15 mg kg^{-1} after the 2nd week and 7 mg kg^{-1} and 13 mg kg^{-1} after the 4th week. These values are basically determined by the soil type. It is clearly observed that the dominant form of the two inorganic nitrogen forms was nitrate. Soil nitrate concentrations were four to five times higher than ammonium. In addition, the soil ammonium content showed a slight decrease by the fourth week, similar to the pH values. Treatments had no significant effect on the soil ammonium content compared to the control.

Our results pointed out that to explore the mechanism of prototype product further investigations are needed. In the future, studying the effects of the prototype product in different soils is necessary to state general recommendations of usage. Furthermore, beside soil chemical analysis, soil microbiological analysis is planned to study the effects of the products on soil microbiological activity. In addition, a longer study period is planned to study the effects of the products over a longer period.

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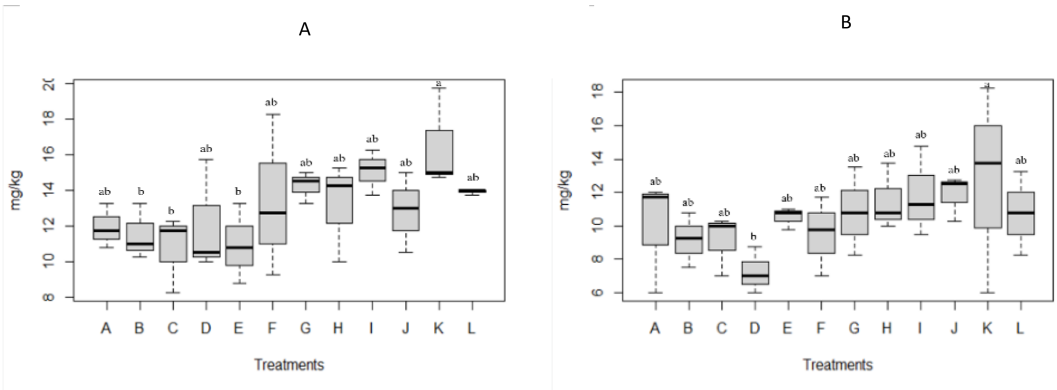
Figure 4AB: **Effect of treatments on soil ammonium content after 2nd (A) and 4th (B) week**



In each box plot, means followed by the same letter are not significantly different (P<0.05).

CONCLUSIONS

The following conclusions can be drawn from our results:

- It was found, that the increasing dose of SAP caused significantly lower soil pH. Lower soil pH caused by treatments is better for nutrient uptake. This suggests that the used products resulted in more favorable nutrient uptake conditions.
- Soil EC was decreased during the experiment in all treatments. The salt concentration in the soil solution was not significantly changed by the treatments. This indicates that the used additives do not reduce the nutrient uptake of the soil solution.
- Soil nitrate contents in the control treatment resulted more significant leaching tendency than in the used treatments. It is pointed out, that the increasing SAP content in the products, due to its cross-linked structural property, protected the nitrate ions from the leaching.
- The dominant form of the two studied inorganic nitrogen forms was nitrate. It can be explained by the used water capacity level. The 60% water capacity level was appropriate for mineralization processes in this soil type.
- Our results suggest that applied SAP does not bind the nutrient ions so tightly in its structure that it competes with the plant for uptake. It means, that the physio- and/or chemisorption inside the SAP is not so strong that they inhibit the uptake of nutrients by the plants.

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