

## STUDY OF THE MINERALISATION OF PELLETIZED CHICKEN MANURE AT DIFFERENT SOIL MOISTURE CONTENT OF A SANDY SOIL

Nagy Péter Tamás\*#, Karanja Mary\*, Magyar Tamás\*

\*University of Debrecen, Faculty of Agricultural and Food Sciences and Environmental  
Management, Institute of Water and Environmental Management, Böszörményi St. 138,  
Debrecen, Hungary, e-mail: [nagypt@agr.unideb.hu](mailto:nagypt@agr.unideb.hu)

### Abstract

*This study evaluates the effect of soil moisture content on mineralization process of composted and pelletized chicken manure on pH, nitrate and ammonium contents at a sandy soil. To establish the mineralisation rate of the composted chicken manure in the soil a short soil incubation method was used.*

*The objectives of the study were: (1) To assess the effects of three types of composted chicken manure on soil pH at different moisture contents conditions, (2) To assess the effects of the three types of composted poultry manure on soil easily soluble mineralised N forms (nitrate and ammonium) at different moisture contents. For study of mineralisation rate of composted and admixtured chicken manure pellet a short soil incubation experiment was set up. Beside the control three treatments, each containing 12 pots (three replicates for soil samples with four different moisture content; 40 %, 50 %, 60 % and 70 %) were used. The pH value and nitrate and ammonium contents and their changing were assessed after the first, second, third and fourth weeks respectively. In each of the four experiment blocks, the soil samples were subjected to four treatments: control, P+K, P+K "C", and Humin Plus.*

*Statistical analysis of the data showed that the three manure types had significant impact on the soil nitrate and ammonium levels at different soil moisture conditions. No significant effect on soil pH was identified during the experiment period. This implies that in order to achieve optimum benefits from application of chicken manure on the farm, it is necessary to do soil testing to assess the nitrate and ammonium status of the soil first. This can provide a basis to make a well-informed decision on which manure is the best in the supply of either nitrate and ammonium to the soil depending on the soil amendment needs.*

**Key words:** mineralization of chicken manure, soil incubation, easily soluble N forms of soil, organic fertilization

### INTRODUCTION

Mineralisation and so the nutrient supply of organic manures is a cardinal problem of farmers mainly at sandy soils where the sufficient mineralisation processes are often hindered (Tamás, Nagy, 2009). Moreover, the potential for N mineralization varies among different organic amendments. This implies that the type and dose of amendment and application timing should meet the crop's nutritional needs. Furthermore, soil properties, like temperature, moisture soil enzyme activity, soil microorganisms and organic matter content basically determine the mineralisation processes. Hydrological condition can significantly influence the decomposition, output and accumulation of organic matter and thus

---

# Corresponding author

affect the cycling and availability of soil nutrients (Mitsch, Gosselink, 2007; Nagy et al., 2018).

To find a stable organic matter source to improve soil properties is essential for the future's growers. Over the last three decades there has been a great increase in the production of waste from urban, industrial and mainly agricultural activity that could be recycled as a source of plant nutrients, and used to enhance soil quality. The use of these materials could partially offset the need for mineral fertilizers, giving both economic and environmental benefits (Cordovil et al., 2005).

Intensification of cattle, swine, and poultry operations is projected to continue in both developed and developing countries, with annual increases in production through 2050 estimated at 0.5 % and 1.7 %, respectively (Alexandratos, Bruinsma, 2012). As such, the collection and spreading of manure will also increase in the future.

Hungary was responsible for about 3.5 % of the European Union's total poultry meat production in 2018, according to Eurostat, (the European Commission's official statistics directorate-general). And the EU produced a record 15.2 million tonnes of poultry meat in 2018. This represents a cumulative rise of about one quarter or 3.2 million tonnes since 2010, Eurostat says. Therefore, it is very important that how to use manures which are potentially dangerous for environment when used them without composting.

In order to achieve quick disposal of poultry manure and prevent the loss of nutrients from the manure and avoid pollution of the environment, poultry manure may be utilized in land applications as fertilizer. It is widely known that chicken manure is very high in nitrogen and also contains a good amount of potassium and phosphorus (Szabó et al., 2019). But, the chicken manure as waste from the poultry industry includes a mixture of excreta (manure, feces and urine), bedding material or litter (e.g. wood shavings or straw), waste feed, dead birds, broken egg sand feathers removed from poultry houses. Other wastes include those from cage, conveyer belt and water-flushing systems. Poultry manure is acquired through regular cleaning of the poultry house (Kobierski et al., 2017).

The litter and manure component of this waste has a high nutritional value and is used as an organic fertiliser, thus recycling nutrients such as nitrogen, phosphorous and potassium. These components (poultry litter) have traditionally been land spread on soil as an amendment. The mature compost can improve soil fertility and plant growth (Haga, 1999). However, immature compost applied to soil would cause N starvation (Bernal et al., 2009; Moral et al., 2009), phytotoxic effects, and presence of harmful microbes (Fang et al., 1999; Tiquia, Tam, 2000).

Measurement of mineralisation rate and circumstances of the biomass nitrogen is essential in understanding the fate of manure nitrogen following soil application. As investigated by Bhat et al., 2015, soils that receive organic manure and integrated nutrient management have high rates of nitrogen mineralization at optimum time periods and temperatures.

Moreover, when the rates of nitrogen mineralization of poultry litter are compared with that of conventional fertilizer, it can be deduced that upon application, poultry manure is a better alternative to the conventional fertilizer as suggested by Hirzel et al., 2010.

The high nitrogen and balanced nutrients is the reason that chicken manure compost is the best kind of manure to use. But the high nitrogen in the chicken manure is dangerous to plants if the manure has not been properly composted. Raw chicken manure fertilizer can burn, and even kill plants. Moreover, over-application of this material can lead to an enriching of water nutrients resulting in eutrophication of water bodies, the spread of pathogens, the production of phytotoxic substances, air pollution and emission of greenhouse gases (Fan et al., 2000; Kelleher et al., 2002). Bitzer and Sims, 1988 reported that excessive application of poultry litter in cropping systems can result in nitrate contamination of groundwater. Excessive application of fresh poultry manure on the farm may result to excess accumulation of ammonia hence may damage the crop roots (Köteles, Pereş, 2017; Tamás et al., 2017). In order to prevent excessive application of the manure and potentially causing ground water and surface water contamination, it is essential to prepare a worksheet to manage the nutrient budget for each crop of field.

Proper handling of the manure can be achieved through proper manure composting and appropriate practices of feed management (Bolan et al., 2010). Properly composted poultry manure results into effective nitrogen mineralization hence reducing nitrate leaching and the harmful environmental effects of excess ammonia. Nahm, 2005, recommends that poultry manure should be applied to soil at rates that are determined by the level of soil - available N and the amounts of nitrogen required by the crops. When the soil samples are incubated at optimum soil moisture (approximately 40 %) the soil sample nitrate level are expected to increase significantly due to optimum microbial activity in the soil that encourage nitrification to occur. However, if the soil samples are incubated at waterlogged conditions (60 – 70 %) it is expected that the ammonium levels will be significantly higher compared to nitrates due to anaerobic conditions that limit conversion of ammonium to nitrates. In waterlogged soil conditions, the soil bacteria are made to use nitrate as an energy source, hence facilitating for denitrification process where the  $\text{NO}_3^-$  is converted to

NO<sub>2</sub><sup>-</sup> and ultimately into nitrogen gas (N<sub>2</sub>) that escapes into the atmosphere (Marin et al., 2016).

## MATERIAL AND METHOD

Soil samples were collected from the Pallag Experimental Station area of Institute of Horticultural Science of University of Debrecen in Hungary. After that soil was pretreatment: dried, sieved and removed the possible dirt. The dominant type of soil in Pallag area is sandy soil. The basic parameters of the Pallag soil were as follows (Table 1).

Table 1

Basic parameters of Pallag soil

Pallag soil basic soil parameters	Value
pH (KCl)	5.50
Plasticity index (KA)	35.00
Water soluble salts (m/m)%	0.02
Carbonate (m/m)%	< 0.10
Humus (org. C) (m/m)%	2.05
Phosphor pentoxide (mg/kg) (AL)	259.00
Potassium-oxide (mg/kg) (AL)	490.00
Nitrate (mg/kg) (KCl)	18.20
Sodium (mg/kg) (AL)	49.80
Magnesium (mg/kg) (KCl)	114.00
Sulphur (mg/kg) (KCl)	4.98
Manganese(mg/kg) (EDTA)	173.00
Zinc (mg/kg) (EDTA)	4.12
Copper (mg/kg) (EDTA)	3.40
Organic Nitrogen (m/m)%	0.11

Soil is a slightly acidic sandy soil with larger humus content. Water soluble salts and carbonate content are low. Nitrogen availability is medium but phosphorous and potassium content of the soil are high according to the regular significant P and K fertilization management. Micronutrient concentrations (Zn, Cu) are medium with significant Mn content in the upper soil layer.

### Experimental design

500 g of the air dried soil was placed in each experiment pot where 400 g of the soil sample was first put into the pots, then four weighted pellets of composted chicken manure, as calculated from manufacturer's

recommendation, were put on the soil samples in the pots and then the pellets were covered with another 100 g of soil. All treatments containing 12 pots (3 replicates for soil samples with four different moisture contents; 40 %, 50 %, 60 % and 70 %) were used. The pH, nitrate and ammonium content were measured after the first, second, third and fourth weeks respectively.

Beside the control the applied treatments were: P+K, P+K "C", and Humin Plus. The contents of the applied products were as follows:

- P+K: 60 % composted chicken manure, 15 % meat powder, 15 % superphosphate and 10 % potassium-sulphate,
- P+K „C": 60 % composted chicken manure, 15 % meat powder, 15 % superphosphate, 10 % potassium-sulphate and 0.4 % zinc-sulphate,
- Humin Plus: 50 % composted chicken manure, 20 % meat powder, 20 % superphosphate, 10 % dudarite (clay mineral) and 0,4 % zinc-sulphate.

During the experiment, the pots were divided into two main parts: the upper part was surrounding the pellets and the lower part was situated below the pellets. 10 g of soil from the upper part of the pots (surrounding the placement area of the manure) and 10 g of soil at the bottom of the pots were collected from each sample and labelled as "upper" and "lower" layer, respectively. A total of 24 sub-samples were made out of the replicates from each block. Soil extraction was done by adding 25 ml of 1M KCl to each sub-sample according to the Hungarian Standard (MSZ 20135, 1999). The contents were placed in a shaker, for one hour and then filtered. The filtrate was collected in test tubes to measure the experiment variables. The first variable to be measured was the soil pH using a pH meter (HANNA HI 2550). The nitrate and ammonium content were measured by photometrical methods used PF 12 spectrophotometer.

### **Statistical analysis**

All the obtained data were tabulated and statistically analyzed using the L.S.D. test at 5 % level to recognize the significance of the differences between various treatment methods. The effects of the different treatments were assessed within ANOVA and Fisher's least significant differences were calculated following a significant ( $P \leq 0.05$ ) F test.

## **RESULTS AND DISCUSSION**

### **Effect of the applied manures on soil pH**

The measured soil pH values of different treatments are not showed in this study but the results of statistical probes are showed in Table 2.

At 40 % soil moisture content, there were significant differences in the pH ( $p < 0.05$ ) for the lower sub-samples of the experiment treatments. This was attributed to the activation of soil microorganisms in the samples as water was introduced to the soil at optimal levels for microbial physiological activities. In their study to identify the relationship between soil moisture content and the development and growth of microorganisms, Borowik and Wyszowska, 2016, found out that the optimal soil moisture content for the development and activity of actinomycetes and Azotobacter was 40 % of the soil's maximum water capacity. Upon respiration during growth and development, the microorganisms in the soil samples released carbon dioxide ( $\text{CO}_2$ ) that reacted with the water hence resulting to formation of weak carbonic acid that dissociated in the soil and released hydrogen and carbonate ions (Strawn, et al., 2019). The carbon dioxide released in the lower soil could not escape easily hence was retained in the soil and the acidic hydrogen ions ( $\text{H}^+$ ) affected the pH of the lower soil. At 40 % moisture content, the lower sub-samples demonstrated significant variations in the pH values, a phenomenon that could be attributed to differences in the levels of microbial activities and release of  $\text{CO}_2$  in the soil samples. In the upper soil, some of the carbon dioxide easily escaped into the atmosphere. This explains why there were no significant differences in the pH values ( $p > 0.05$ ) for the upper sub-samples at this moisture content level.

Table 2

P-values obtained from ANOVA test of the pH data at different soil moisture levels

Moisture level		40 %	50 %	60 %	70 %
pH	Lower layer	0.014198	0.218566	0.34621	0.637979
<i>p-values</i>	Upper layer	0.307131	0.3769	0.431725	0.246183

At 50 %, 60 % and 70 % soil moisture contents, there were no significant statistical differences in the pH values of the soil as all  $p$  - values were greater than 0.05 in all lower and upper sub-samples. The original pH value of the Pallag soil was 5.50 (see Table 1) before amendment with poultry manure pellets. The pH of the manure pellets was 6.6. After amendment with the manure, the pH values recorded for all the samples ranged between  $6.54 \pm 0.173$  and  $6.79 \pm 0.826$  at the end of the 4-weeks experiment period. The variations of the pH values recorded after manure application on the soil were statistically insignificant. It can be inferred that, manure pellets were not alkaline or acidic enough to significantly alter the soil's original pH status. With subsequent increase in moisture content of soil beyond the optimal level (40 %), the microorganism's respiration activity and release of carbon dioxide was gradually limited due to

saturation of the pores in the soil matrix with water hence the insignificant changes in the soil pH at 50 %, 60 % and 70 % soil moisture content. Limited microbial respiration processes, accounted for the insignificant changes in either reduction or increase in the soil pH after manure application at 50 %, 60 % and 70 % soil moisture contents.

### **Effect of the applied manures on soil nitrate content**

The measured soil nitrate-values of different treatments are showed in Table 3-6. The effects of length of incubation time and moisture content are investigated and presented in these tables.

Table 3 above shows the nitrate levels obtained from the control treatment. The results pointed out that the studied soil has a significant amount of nitrate ranged between 15 and 35 mg/kg in the lower and between 6 and 29 mg/kg in the upper layer. For lower sub-samples, the figures showed an increasing trend that appeared to level off and drop after week 3 at all moisture contents. For upper sub-samples, nitrate levels showed a steady increasing from week 1 to week 4, for all moisture contents. It can be explained by the effect of soil moisture on the amount of nitrate. In dry soils, microbes can't convert the organic materials into inorganic forms such as nitrates.

*Table 3*

Effects of control on soil nitrate content at different soil moisture level during the incubation period

moisture level (%)	Soil nitrate content (mg/kg)							
	Upper layer				Lower layer			
	weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	11.23	17.87	17.77	23.00	25.77	27.60	25.50	25.07
50	7.60	12.40	17.20	22.07	16.27	19.17	34.93	25.57
60	8.67	13.93	19.87	28.80	16.67	21.57	23.43	21.77
70	6.33	12.67	18.47	17.23	14.73	19.80	27.20	27.70

In Table 4, soil nitrate contents obtained from P+K treatment are showed. In the upper layer an enormous, increase of nitrate content can see independently of the soil moisture level. However, in the lower layer this increasing trend can't have observed. More balanced soil nitrate concentrations were measured in this layer. The findings can be explained by the situation of the manure pellets. The soil surrounding the pellets are richer in nitrates than the lower layer. Moreover, the increasing nitrate concentration is observed as the mineralization process proceeds.

In Table 5, the soil nitrate contents obtained from P+K "C" treatment are showed. The nitrate content of the soil was continuously increased in the upper layer in the examined period. The tendency was independent from the

soil moisture level but the degree of the increment strongly affected by the moisture level. The obtained results are almost similar to those of P+K product.

In Table 6, the soil nitrate contents obtained from Humin Plus treatment are showed. Although the nitrate trend shows variations at the different moisture content levels, there is a general decreasing trend from week 1 to week 4 for the lower sub-samples. There is a decline in the values from week 1 to week 2, from about 5.7 - 8.2 to about 4.3 - 5.2. Then the values slightly increase and stabilized from week 3 to week 4. For the upper subsamples, there is a sharp increase in the values from week 1 to week 2 and later an enormous drop in the third week, which was increased again to the fourth week.

Table 4

Effects of P+K treatment on soil nitrate content at different soil moisture level during the incubation period

moisture level (%)	Soil nitrate content (mg/kg)							
	Upper layer				Lower layer			
	weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	9.33	17.83	22.97	24.97	30.00	26.53	25.47	31.10
50	17.20	10.17	18.87	25.53	23.13	22.70	21.00	25.47
60	11.47	9.37	17.20	19.30	23.93	18.30	18.53	26.57
70	4.43	8.13	20.29	14.63	27.73	21.73	25.29	20.97

Table 5

Effects of P+K "C" treatment on soil nitrate content at different soil moisture level during the incubation period

moisture level (%)	Soil nitrate content (mg/kg)							
	Upper layer				Lower layer			
	weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	12.40	11.40	18.33	20.70	28.63	24.10	18.53	21.63
50	12.30	13.93	17.10	21.80	17.23	17.33	16.77	14.93
60	6.47	10.43	16.73	19.67	21.93	24.43	15.53	19.93
70	4.67	10.23	12.47	15.03	16.97	16.87	13.90	16.87

Table 6

Effects of Humin Plus treatment on soil nitrate content at different soil moisture level during the incubation period

moisture level (%)	Soil nitrate content (mg/kg)							
	Upper layer				Lower layer			
	weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	9.20	11.87	4.23	6.07	5.67	5.27	5.20	4.37
50	4.25	8.63	4.40	4.53	8.15	4.87	4.83	5.47
60	6.90	8.70	4.03	5.90	6.73	4.40	5.70	4.37
70	7.60	7.07	4.10	4.47	6.20	4.33	5.47	5.53

In reference to Table 7, at all moisture contents 40 %, 50 %, 60 % and 70 %, there were significant differences in the nitrate values as they were less or equal to 0.05 ( $P \leq 0.05$ ) under all the experiment treatments over the four-week period. High nitrate contents were recorded at 40 % soil moisture content while the lowest nitrate concentration was recorded under the highest soil water content (70 %).

Table 7

P-values obtained from ANOVA test of the nitrate data at different soil moisture levels

Moisture level		40%	50%	60%	70%
NO <sub>3</sub> <sup>-</sup> <i>P-values</i>	Lower layer	0.00000465	0.001086	0.000587	0.0000704
	Upper layer	0.008965	0.05067	0.052006	0.030062

Among the three manure type treatments, P+K recorded the highest nitrate release in the soil at 40 % soil moisture content levels conditions in both lower and upper subsamples (maximum value was 30.00 mg/kg), and Humin plus released the lowest amount of nitrate in the soil (maximum value was 11.87 at 40 % moisture content) in the upper sub-samples as seen in tables above.

High nitrate contents in the soil can be attributed to a high rate of nitrification process facilitated by the aerobic soil microorganisms at moderate water content levels (40 %) due to adequate soil aeration. As the moisture content of the soil increases, the soil becomes more waterlogged over time as in the cases where the soil has more than 40 % water content due to continuous irrigation.

In water-logged conditions, soil microorganisms are unable to effectively mineralize the organic nitrogen into nitrates as oxygen supply in the soil matrix is inhibited by the saturated soil conditions (Castaldelli et al., 2019). Other than the aspect of soil water content, it can be inferred that P+K manure is the best choice to supply nitrates to the soil at moderate soil moisture conditions. Humin plus is a poor choice for nitrates supply in the soil as demonstrated by the negative trends in the nitrate values obtained after soil application as demonstrated in table 6 above.

Generally, there is a clear increasing trend in the nitrate values recorded for all upper subsamples in all treatments except for the Humin Plus treatment, as demonstrated in Tables 4 - 6 above. However, many variations are observed in the lower sub-sample nitrate values. This observation can be attributed to the higher exposure of upper subsamples to air compared to the lower subsamples. Adequate soil aeration is an important factor to consider in the nitrification process, and in the nitrate distribution between layers also important factor is the leaching process of nutrients.

### Effect of the applied manures on soil ammonium content

The measured soil ammonium contents of different treatments are showed in Tables 8 - 11. The effects of length of incubation time and moisture content are investigated and presented in these tables.

Table 8 shows the soil ammonium contents obtained from the control treatment. The ammonium values demonstrated an increasing trend from week 1 to week 2 and dropped progressively by week 4 at all moisture contents in the lower and upper sub-samples.

Table 8

Effects of control on soil ammonium content at different soil moisture level during the incubation period

moisture level (%)	Soil ammonium content (mg/kg)							
	Upper layer				Lower layer			
	weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	2.50	5.81	5.47	1.43	1.83	8.67	7.47	2.83
50	1.77	5.99	3.17	1.67	2.07	5.83	5.33	3.00
60	2.20	5.96	2.83	1.00	2.40	4.83	5.00	1.17
70	1.60	6.13	5.17	1.67	1.87	3.33	2.03	0.83

Table 9 shows the soil ammonium contents obtained from the P +K treatment. The ammonium values demonstrated a continuous decreasing trend at all moisture contents in the upper and lower sub-samples during the incubation period.

Table 9

Effects of P+K treatment on soil ammonium content at different soil moisture level during the incubation period

moisture level (%)	Soil ammonium content (mg/kg)							
	Upper layer				Lower layer			
	weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	8.67	1.67	3.67	0.83	7.67	2.67	2.67	1.23
50	7.33	2.00	4.33	0.97	6.67	1.33	2.67	1.00
60	7.33	1.67	4.00	0.83	5.00	2.00	3.67	0.77
70	11.67	3.33	4.00	0.83	5.33	1.33	2.67	0.73

Table 10 shows the soil ammonium contents obtained from the P+K “C” treatment. Both upper and lower subsamples show a progressive decreasing trend for the soil ammonium at all moisture content levels. Moreover, a bit higher values are observed in the upper subsamples compared to the lower subsamples.

Table 11 shows the soil ammonium contents obtained from the Humin Plus treatment. In both upper and lower subsamples, the ammonium levels

drop in the second week and then increase sharply to week 3 after which the levels slightly drop again. The highest soil ammonium contents were observed at 70 % moisture content in both upper and lower sub-samples.

Table 10

Effects of P+K “C” treatment on soil ammonium content at different soil moisture level during the incubation period

moisture level (%)	Soil ammonium content (mg/kg)							
	Upper layer				Lower layer			
	Weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	8.33	6.40	1.73	0.77	8.00	4.37	1.13	0.57
50	9.67	6.39	1.17	0.53	7.67	4.30	0.77	0.50
60	10.67	6.39	2.20	0.60	8.67	3.80	0.63	0.63
70	12.00	6.41	2.77	0.50	7.67	3.90	0.60	0.43

Table 11

Effects of Humin Plus treatment on soil ammonium content at different soil moisture level during the incubation period

moisture level (%)	Soil ammonium content (mg/kg)							
	Upper layer				Lower layer			
	Weeks							
	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>	1 <sup>st</sup>	2 <sup>nd</sup>	3 <sup>th</sup>	4 <sup>th</sup>
40	6.47	4.50	16.00	13.33	7.63	6.20	13.00	11.33
50	6.73	3.57	15.00	21.67	7.03	5.67	14.33	8.33
60	6.60	5.00	17.00	14.67	7.83	6.07	14.33	13.00
70	5.27	6.20	18.00	16.00	7.60	6.23	16.33	12.67

As shown in Table 12, at all the four soil moisture conditions, there were significant differences in ammonium content ( $P \leq 0.05$ ) for all the sub-samples at 40 %, 60 %, 70 % and 50 % moisture conditions.

Table 12

P-values obtained from ANOVA test of the ammonium data at different soil moisture levels

Moisture level		40%	50%	60%	70%
NH <sub>4</sub> <sup>+</sup> P-values	Lower layer	0.014198	0.02096	0.009296	0.005666
	Upper layer	0.05336	0.076097	0.044853	0.026087

However, there was no significant difference in the soil ammonium at 40 and 50 % (upper sub-samples) soil moisture condition by the end of the experiment period. Humin plus released the highest amount of ammonium in the soil compared to the other two manure products. High soil ammonium content in the highest soil water content can be associated with a more anaerobic environment that inhibits conversion of ammonium to nitrate compared to lower soil water content. Furthermore, the Humin Plus manure product contained 10 % dudarite (clay mineral) that was absent in the other

manure types. Clay minerals have negative charges on their surface that attracts positive cations including ammonium ions hence high levels of  $\text{NH}_4^+$  in the soil samples that were treated with Humin Plus as the clay mineral facilitated for ammonium ion fixation into the soil (Nieder et al., 2011).

Dudarite also stimulates the growth of soil microbes, which accelerate the decomposition of organic matter and increases the capacity of the soil buffering capacity hence resulted favourable conditions for plant growing. It seems that applying Humin Plus product the nitrogen mobilization processes are affected basically. Ammonification process in soil was fortified while the nitrification process was hindered (see the lowest soil nitrate content – Table 6). This effect may be explained by the lower manure, higher meat powder and added dudarite content.

## CONCLUSIONS

In summ, it can be stated that the P+K chicken manure product is the best in nitrate supply on a crop farm irrigation should be done while maintaining the optimal soil moisture content.

Humin Plus is the best chicken manure product for the supply of ammonium. In order to achieve its benefits in supplying soil  $\text{NH}_4^+$  on the farm, the released ammonium content has a great opportunity to convert nitrate as the soil conditions is getting better and better. Moreover, the slightly hindered nitrification (as long-continued N supply) is sometimes desirable, mostly at sandy soils where the nitrate leaching process is enhanced.

## Acknowledgment

The research was carried out and financed by GINOP-2.2.1-15-2017-00043 project at the University of Debrecen.

The research was financed by the Thematic Excellence Programme of the Ministry for Innovation and Technology in Hungary (ED\_18-1-2019-0028), within the framework of the Space Sciences thematic programme of the University of Debrecen.

## REFERENCES

1. Alexandratos N., Bruinsma J., 2012, World agriculture towards 2030/2050: the 2012 revision. ESA Working paper No.12-03. Rome, FAO;
2. Bernal M.P., Albuquerque J.A., Moral R., 2009, Composting of animal manures and chemical criteria for compost maturity assessment. A review. *Bioresour. Technol.*, 100 (22), pp.5444-5453;
3. Bhat Z.A., Saroa G.S., Benbi D.K., Choudary O.P., Padder S.A., 2015, Nitrogen mineralization kinetics in soil incubated at different temperatures amended with organic and inorganic fertilizers. *The Ecoscan*, 9(3&4), pp.699-703;
4. Bitzer C.C., Sims J.T., 1988, Estimating the availability of nitrogen in poultry manure through laboratory and field studies. *J. Environ. Qual.* 17, pp.47-54;

5. Bolan N.S., Szogi A.A., Chuasavathi T., Seshadri B., Rothrock M.J., Panneerselvam P., 2010, Uses and management of poultry litter. *World's Poultry Science Journal*, 66(4), pp.673-698;
6. Borowik A., Wyszowska J., 2016, Soil moisture as a factor affecting the microbiology and biochemical activity of soil. *Plant, Soil and Environment*, 62(6), pp.250-255;
7. Castaldelli G., Colombani N., Soana E., Vincenzi F., Fano E.A., Mastrocicco M., 2019, Reactive nitrogen losses via denitrification assessed in saturated agricultural soils. *Geoderma*, 337, pp.91-98;
8. Cordovil C.M.D.S., Coutinho J., Goss M., Cabral F., 2005, Potentially mineralizable nitrogen from organic materials applied to a sandy soil: fitting the one-pool exponential model. *Soil Use and Management*, Vol.21. (1), pp.65-72;
9. Fan Z.J., Ai Y.W., Li J.M., Li G.W., 2000, Discussion of controlling N loss from volatilization in animal manure. *J. Sichuan Normal Univ. (in Chinese)* 23 (5), pp.548-550;
10. Fang M., Wong J.W.C., Ma K.K., Wong M.H., 1999, Co-composting of sewage sludge and coal fly ash: nutrient transformations. *Bioresour. Technol.* 67, pp.19-24;
11. Haga K., 1999, Development of composting technology in animal waste treatment-review. *Asian Austral. J. Anim. Sci.* 12 (4), pp.604-606;
12. Hirzel J., Undurraga P., Walter I., 2010, Nitrogen mineralization and released nutrients in a volcanic soil amended with poultry litter. *Chilean Journal of Agricultural Research*, 70(1), pp.113-121;
13. Kelleher B.P., Leahy J.J., Henihan A.M., O'Dwyer T.F., Sutton D., Leahy M.J., 2002, Advances in poultry litter disposal technology – a review. *Bioresource Technology* 83, pp.27-36;
14. Kobiński M., Bartkowiak A., Lemanowicz J., Piekarczyk M., 2017, Impact of poultry manure fertilization on chemical and biochemical properties of soils. *Plant, Soil and Environment*, 63(12), pp.558-563;
15. Köteles N., Peres A.C., 2017, The level of air pollution with ammonia in the city of Satu Mare in 2014-2016. *Natural Resources and Sustainable Development* 7, pp.57-60;
16. Marin J.C.A., Caravelli A.H., Zaritzky N.E., 2016, Nitrification and aerobic denitrification in anoxic-aerobic sequencing batch reactor. *Bioresource technology*, 200, pp.380-387;
17. Mitsch W.J., Gosselink J.G., 2007, *Wetlands*. 4th Ed., John Wiley & Sons, Hoboken;
18. Moral R., Paredes C., Bustamante M.A., Marhuenda-Egea F., Bernal M.P., 2009, Utilization of manure composts by high-value crops: safety and environmental challenges. *Bioresour. Technol.* 100 (22), pp.5454-5460;
19. MSZ 20135, 1999, Determination of the soluble nutrient element content of the soil. Hungarian Standards Institution. Budapest (in Hungarian);
20. Nagy A., Fehér J., Tamás J., 2018, Wheat and maize yield forecasting for the Tisza river catchment using MODIS NDVI time series and reported crop statistics. *Computers and Electronics in Agriculture* 151, pp.41-49;
21. Nahm K., 2005, Factors influencing nitrogen mineralization during poultry litter composting and calculations for available nitrogen. *World's Poultry Science Journal*, 61(2), pp.238-255, doi:10.1079/WPS200455;
22. Nieder R., Benbi D.K., Scherer H.W. 2011, Fixation and defixation of ammonium in soils: a review. *Biology and Fertility of Soils*, 47(1), pp.1-14;

23. Strawn D.G., Bohn H.L., O'Connor G.A., 2019, Soil chemistry. John Wiley & Sons;
24. Szabó A., Tamás J., Nagy A., 2019, Spectral evaluation of the effect of poultry manure pellets on pigment content of maize (*Zea mays L.*) and wheat (*Triticum aestivum L.*) seedlings. Natural Resources and Sustainable Development 9:1, pp.70-79;
25. Tamás J., Nagy A., 2009, Advanced Evaluation of Spatial Inhomogeneity of Light Sandy Soil. Analele Universității din Oradea, Fascicula Protecția Mediului, 14, pp.364-374;
26. Tamás J., Gorliczay E., Borbély J., 2017, Atmospheric spreading model for ammonia released from the poultry house. Analele Universității din Oradea, Fascicula Ecotoxicologie, Zootehnie și Tehnologii de Industrie Alimentară, 15, pp.331-338;
27. Tiquia S.M., Tam N.F.Y., 2000, Fate of nitrogen during composting of chicken litter. Environmental Pollution 110, pp.535-541.

Received: March 25, 2020

Revised: May 11, 2020