

# Effect of Sewage Sludge Amended Soil on Maize Crop

## I. Influence on yield and mineral nutrition

LEONARD ILIE<sup>1</sup>, MIRCEA MIHALACHE<sup>1</sup>, ROXANA MARIA MADJAR<sup>1</sup>, CATALINA CALIN<sup>2</sup>, GINA VASILE SCAETEANU<sup>1\*</sup>

<sup>1</sup>University of Agronomic Sciences and Veterinary Medicine of Bucharest, 59 Marasti Blvd., 011464, Bucharest, Romania

<sup>2</sup>Petroleum-Gas University of Ploiesti, 39 Bucharest Av., 100680, Ploiesti, Romania

*The aim of the present study was to evaluate the efficiency of sewage sludge application on maize (*Zea Mays L.*) growth, yield and macrolelements accumulation (N, P, K, Ca, Mg) when different doses of sewage were applied accompanied by mineral fertilization. The results indicated that sewage sludge fertilization produces significant increase of maize yield that are evident starting with 200 kg N/ha rate, and the highest increases were recorded in the rate of 400 kg N/ha. The nitrogen content in the maize leaves increased significantly in the variants fertilized with sludge at a rate over 300 kg N/ha, meanwhile the potassium content of the maize leaves was significantly reduced as a result of sludge fertilization at a rate equivalent to 400 kg N/ha. Nitrogen and phosphorus contents in the maize kernels increased with sewage sludge loading, meanwhile in the case of potassium the data showed that there were no statistically significant changes in the potassium content of the maize kernels under the influence of sewage sludge fertilization. The application of sewage sludge caused a significant increase of the calcium and magnesium contents in the maize leaves at equivalent rates higher than 200 kg N/ha.*

*Keywords: crop productivity, fertilization, maize, sewage sludge, waste management*

Sewage sludge contains important amounts of nutrients that are indispensable to plant growth. Nitrogen availability from sewage sludge depends on inorganic N content, C/N ratio, soil type and application method and timing [1].

Accordingly, an alternative to the application of fertilizers may be application of sewage sludge resulted from water treatment plants [2]. The fertilizer effect enables a reduction in cost for nitrogen and phosphorus mineral fertilizers and may improve crops yield on sludge treated fields [2,3].

Some studies indicated that successive application during seven years of 100 t/ha municipal sewage sludge for wheat and maize crops produced an increase with a percent of organic carbon from soil [4,5]. Other studies concerning the influence of sewage sludge application on soil properties and on the growth of wheat and corn plants indicated that soil pH increased to neutral. Also, organic matter content, electrical conductivity and available phosphorus increased after sewage application [6,7].

Considerable research has been accomplished worldwide on the use of sewage sludge on soil and crop. In many investigations with different climatic and soils conditions have reported a substantial increase in plant growth, crop yield and biomass production upon sewage sludge application [8-12].

There are many advantages of sewage sludge application to agricultural soils, the main one being represented by the positive effects on crop yields. Hence, experiments consisting in application of 0, 40, 80, 120 t/ha sewage sludge at rice grain evidenced that rate of 240 t/ha produced highest number of filled grains per panicle, dry weight of grains and weight of 1000 grains [13].

Some studies revealed [14] that sludge doses of 80, 130 and 160 t/ha increased the average dry weight of sunflower plants (*Helianthus annuus L.*) in comparison with those grown on un-amended soil. Also, positive effects on yield of dwarf bean [15] and growth of flax [16] have been reported when different doses of sewage sludge were applied.

Investigation of the effects of sewage sludge application on maize yield under field conditions evidenced that the greatest growth is obtained when 12t/ha sewage sludge + 350 kg/ha urea were applied with 20% more than mineral fertilization, followed by the situation when 8t/ha sewage sludge + 350 kg/ha urea that was with 10% more than mineral fertilization [17].

Gaining a lot of popularity over last decades in Europe, maize became one of the most important silage plants due to great adaptability, high yield and various uses: grain for human and animal consumption, forage crop and raw material for different industrial branches. Literature studies indicate that high maize yields can be achieved with adequate supply and balance of essential nutritive elements [18].

Therefore, the purpose of the present study was to evaluate the suitability use of sewage sludge for maize crop (*Zea mays L.*) by evaluating the growth and yield responses and also, macronutrients (N, P, K, Ca, Mg) accumulation. It was used different sewage sludge rates associated or not with mineral fertilization.

The experimental developed model was a bifactorial one (7x2) and the studied factors were: A factor - sewage sludge fertilization with seven degrees representing equivalent doses varying between 0-600 kg/ha and B factor - mineral fertilization (NPK) with two degrees:  $b_1 - N_0P_0K_0$  and  $b_2 - N_{100}P_{100}K_{100}$ .

### Experimental part

#### Material and methods

##### Experimental design

In order to study the influence of sewage sludge application on crop quality and yield, in experimental pots were used as test plant maize (*Zea mays L.*).

The experimental developed model was a bifactorial one (7x2) and the studied factors were: **A factor** - sewage sludge fertilization with seven degrees representing equivalent doses varying between 0-600 kg N/ha (**a<sub>1</sub>**- unfertilized with sewage sludge; **a<sub>2</sub>**- fertilizations with

\* email: ginavasile2000@yahoo.com

sewage sludge corresponding to 100 kg N/ha; **a**<sub>3</sub> - fertilizations with sewage sludge corresponding to 200 kg N/ha; **a**<sub>4</sub> - fertilizations with sewage sludge corresponding to 300 kg N/ha; **a**<sub>5</sub> - fertilizations with sewage sludge corresponding to 400 kg N/ha; **a**<sub>6</sub> - fertilizations with sewage sludge corresponding to 500 kg N/ha; **a**<sub>7</sub> - fertilizations with sewage sludge corresponding to 600 kg N/ha) and **B factor** - mineral fertilization (NPK) with two degrees: **b**<sub>1</sub> - N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> and **b**<sub>2</sub> - N<sub>100</sub>P<sub>100</sub>K<sub>100</sub>.

For experimental model there were used 56 vegetation pots (20 L capacity), each of 14 treatments in four repetitions. The same experimental scheme was adopted previously to investigate the suitability use of sewage sludge for sunflower (*Helianthus annuus* L.) [11].

For experiments was used soil collected from A<sub>0</sub> horizon of luvisol meanwhile sewage sludge that was used in experiment was collected from the Wastewater Treatment Plant (WWTP) from Pitesti.

Soil, sewage sludge and soil after treatments were fully characterized and the used are reported in a previous paper [19].

### Plant sampling and chemical analysis

Plants were taken to the laboratory and it was measured the height of each sample. Then it was partitioned for analysis into leaves and kernels. All these fractions were washed with distilled water to remove soil particles and oven dried at 70°C until constant weight was achieved. The plants were weighted for biomass measurements.

For macronutrients and heavy metals analysis, 1 g of grounded sample passed through a sieve of 2 mm mesh size was digested with 10 mL from a mixture of acids (HNO<sub>3</sub>:H<sub>2</sub>SO<sub>4</sub>:HClO<sub>4</sub>, 5:1:1) till a transparent color appeared [20].

Total nitrogen content was evaluated using Kjeldahl method (*Gerhardt Vapodest automatic analyzer*), meanwhile total phosphorus was assessed spectrophotometrically as molybdenum blue (*Cecil 2041 UV/VIS spectrophotometer*) and potassium using flame photometry method (*Sherwood Scientific 420 flame photometer*). Contents of calcium and magnesium were determined after filtering the digested samples through atomic absorption spectrometry (*Thermo Scientific AA Spectrometer*).

## Results and discussions

### Brief presentation of soil and sewage sludge chemical characterization

The soil used in this experiment, which was taken from A<sub>0</sub> horizon of Luvisol [21]. It had a loam texture, was moderately acidic (pH 5.2), and had a low carbon organic content (1.19%) and a low content of macronutrients: N<sub>total</sub> - 0.140%, P<sub>AI</sub> - 19 mg/kg and K<sub>AI</sub> - 40 mg/kg.

Sewage sludge has a slightly acidic reaction (pH=6.62 as average) and there are no restrictions for using it on agricultural soils. Organic carbon content is high (27% as average) and it could be used as fertilizer and a source of organic matter, meanwhile N<sub>total</sub> ranges between 1.97-2.09% (2.04% as average), P<sub>total</sub> between 0.75-0.78% (0.77% as average) and K<sub>total</sub> between 0.38-0.41% (0.39 as average). Detailed characterization is presented in a previously published paper [19].

### Influence of sewage sludge application on height and yield

The application of sewage sludge, with or without mineral fertilizers, has resulted in increased maize production, directly proportional with the sludge rate. Thus, the highest yields (54 g DM plant) resulted from the application of a sludge rate equivalent to 600 kg N/ha, while the lowest yield was obtained in the unfertilized control (table 1).

Significant increases in production were recorded starting from the rate equivalent to 200 kg N/ha, and the highest increases were recorded in the rate of 400 kg N/ha; there were no significant differences in yields between the rates of 400-600 kg N/ha.

Mineral fertilization based on N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> also led to a significant increase in maize production. The mixed application of sewage sludge and mineral fertilizers resulted in no statistically assured increases in maize production, as the latter was almost the same as the production resulted from sludge fertilization.

Gondek investigated the effect of sewage sludge application on nitrogen content in maize and on yield. The results indicated that fertilization with sewage sludge and sludge mixture with peat acted significantly better on maize yields than fertilization with mineral salts [22]. Other study [7] evidenced that fertilization with sewage sludge favored yield increase, but the production decreased with the increasing the application rate of sewage sludge (120 t/ha for oats and 90t/ha for sugar beet).

Regarding the maize plant height, it was significantly higher in the pots fertilized with sewage sludge, compared with the unfertilized variants. However, there were no changes in plant height between the organic variants that were fertilized with sludge in rates equivalent to 100-600 kg N/ha. Both mineral and mixed (organic and mineral) fertilization resulted in no significant increases in plant height.

### Influence of sewage sludge application on N, P and K contents in leaves

The nitrogen content in the maize leaves increased significantly in the variants fertilized with sludge at a rate over 300 kg N/ha; the highest values were obtained after

Sewage sludge		Height, cm			Yield, g		
		b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)
a <sub>1</sub>	0 kg N/ha	189	197	193a*	16	23	20a*
a <sub>2</sub>	100 kg N/ha	205	205	205b	22	33	28b
a <sub>3</sub>	200 kg N/ha	215	211	213b	37	41	39c
a <sub>4</sub>	300 kg N/ha	212	210	211b	40	48	44cd
a <sub>5</sub>	400 kg N/ha	213	207	210b	48	49	49de
a <sub>6</sub>	500 kg N/ha	213	208	211b	50	54	52e
a <sub>7</sub>	600 kg N/ha	216	208	212b	54	54	54e
Av.(a)		209a*	207a	-	38a*	43b	-

b<sub>1</sub> - corresponds to N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> (without mineral fertilization)

b<sub>2</sub> - corresponds to N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> (mineral fertilization)

Av. - average

\*Mean values accompanied by same letter (a or b) does not present significant differences (Tukey multiple comparison test - significance level 0.05)

**Table 1**  
INFLUENCE OF SEWAGE SLUDGE APPLICATION (WITHOUT/WITH MINERAL FERTILIZATION) ON HEIGHT AND YIELD

**Table 2**

INFLUENCE OF SEWAGE SLUDGE APPLICATION (WITHOUT/WITH MINERAL FERTILIZATION) ON N, P AND K CONTENTS IN LEAVES

Sewage sludge		N			P			K		
		b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)
a <sub>1</sub>	0 kg N/ha	0.51	0.54	0.53a*	0.070	0.058	0.064a*	0.67	0.77	0.72ab*
a <sub>2</sub>	100 kg N/ha	0.63	0.71	0.67ab	0.063	0.060	0.062a	0.73	0.80	0.77b
a <sub>3</sub>	200 kg N/ha	0.66	0.76	0.71ab	0.067	0.070	0.069a	0.76	0.81	0.79b
a <sub>4</sub>	300 kg N/ha	0.82	0.85	0.84bc	0.065	0.070	0.068a	0.81	0.84	0.83b
a <sub>5</sub>	400 kg N/ha	0.82	0.91	0.87bc	0.083	0.075	0.079a	0.57	0.58	0.58a
a <sub>6</sub>	500 kg N/ha	0.96	0.96	0.96c	0.090	0.082	0.086a	0.56	0.65	0.61a
a <sub>7</sub>	600 kg N/ha	0.84	0.81	0.83bc	0.080	0.083	0.082a	0.61	0.61	0.61a
Av.(a)		0.75a*	0.79a	-	0.074a*	0.071a	-	0.67a*	0.72a	-

b<sub>1</sub> - corresponds to N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> (without mineral fertilization); b<sub>2</sub> - corresponds to N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> (mineral fertilization)

Av. - average; n\*Mean values accompanied by same letter (a or b) does not present significant differences (Tukey multiple comparison test - significance level 0.05)

**Table 3**

INFLUENCE OF SEWAGE SLUDGE APPLICATION (WITHOUT/WITH MINERAL FERTILIZATION) ON N, P AND K CONTENTS IN KERNELS

Sewage sludge		N			P			K		
		b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)
a <sub>1</sub>	0 kg N/ha	1.24	1.26	1.25a*	0.29	0.31	0.30a*	0.37	0.45	0.41a*
a <sub>2</sub>	100 kg N/ha	1.30	1.31	1.31a	0.32	0.33	0.33ab	0.42	0.46	0.44a
a <sub>3</sub>	200 kg N/ha	1.29	1.31	1.30a	0.33	0.32	0.33ab	0.43	0.43	0.43a
a <sub>4</sub>	300 kg N/ha	1.32	1.37	1.35a	0.32	0.31	0.32ab	0.38	0.40	0.39a
a <sub>5</sub>	400 kg N/ha	1.39	1.41	1.40ab	0.32	0.36	0.34ab	0.40	0.44	0.42a
a <sub>6</sub>	500 kg N/ha	1.49	1.53	1.51b	0.33	0.36	0.35ab	0.42	0.44	0.43a
a <sub>7</sub>	600 kg N/ha	1.50	1.55	1.53b	0.36	0.38	0.37b	0.43	0.45	0.44a
Av.(a)		1.36a*	1.39a	-	0.32a*	0.34a	-	0.41a*	0.44a	-

b<sub>1</sub> - corresponds to N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> (without mineral fertilization); b<sub>2</sub> - corresponds to N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> (mineral fertilization); Av. - average

\*Mean values accompanied by same letter (a or b) does not present significant differences (Tukey multiple comparison test - significance level 0.05)

the application of a rate equivalent to 500 kg N/ha, while the lowest were recorded in the unfertilized variants.

The application of mineral fertilizers and sewage sludge associated with mineral fertilizers led to no statistically significant changes of the nitrogen content in the maize leaves. The values were similar to those obtained after fertilization based on sludge only (table 2).

Regarding the evolution of the phosphorus content, the situation was the following: the phosphorus content of the maize leaves recorded no statistically significant changes under the influence of fertilization with sludge at rates equivalent to 100-600 kg N/ha; however, there was a tendency of increasing concentration at rates of 400 kg N/ha.

The potassium content of the maize leaves was significantly reduced as a result of sludge fertilization at a rate equivalent to 400 kg N/ha. No significant changes were recorded in the other experimental variants.

#### *Influence of sewage sludge application (without/with mineral fertilization) on N, P and K contents in kernels*

The nitrogen content of the maize kernels increased significantly compared with the unfertilized variant, starting from the rate equivalent to 500 kg N/ha (table 3).

As with the leaves, the mineral and mixed-fertilized variants recorded no statistically significant changes in the nitrogen content.

Statistically significant increases in the phosphorus content of the maize kernels were recorded only at the maximum rate of sludge equivalent to 600 kg N/ha.

The application of mineral fertilizers only and of mineral fertilizers associated with sludge resulted in no statistically significant changes of the phosphorus content in the maize kernels.

The data on the influence of sludge fertilization, with or without mineral fertilizers, showed that there were no statistically significant changes in the potassium content

of the maize kernels under the influence of sewage sludge fertilization, mineral fertilization or the application of the mixture of sewage sludge and mineral fertilizers.

#### *Correlation between different equivalents nitrogen doses from sludge applied and N, P and K uptake by plant*

The nitrogen and phosphorus content of the leaf and kernel analysis correlated with the nitrogen doses resulting from sludge variants and mineral fertilization reveals very significant correlation coefficients. In the case of applied sludge without mineral fertilization, the corresponding nitrogen doses correlate distinctly significant with the nitrogen content of the maize leaves and significant with the phosphorus content of the maize leaves and kernels.

The potassium content determined in leaves and kernels was not significantly correlated with the experimental variants, except, with a significant correlation, for the potassium content determined in corn leaves at mineral fertilization applied (figs. 1-3).

#### *Influence of sewage sludge application on Ca and Mg contents in leaves*

The application of sewage sludge caused a significant increase of the calcium content in the maize leaves at equivalent rates higher than 200 kg N/ha (table 4).

The N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> mineral fertilization led to a significant increase of the calcium content. The application of sewage sludge mixed with mineral fertilizers resulted in statistically unsecured increases in the calcium content of the maize leaves. The values were very close to those obtained in the sludge-fertilized variants.

The lowest calcium concentrations in the leaves were obtained in the control variants while the highest were recorded in the variants fertilized with the highest rate of sludge.

The magnesium content in the maize leaves increased with the sludge rate. Statistically significant changes were

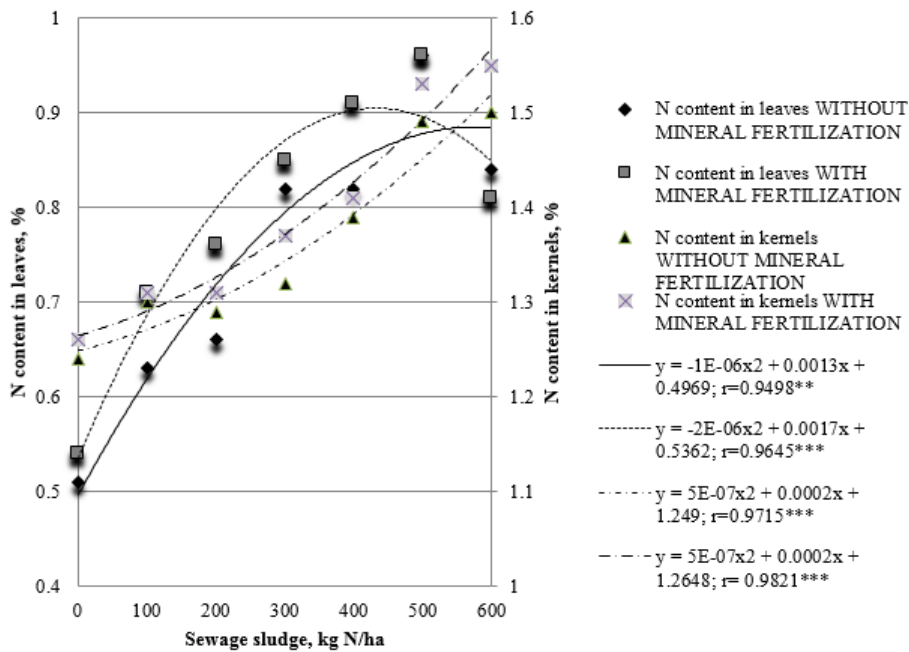


Fig. 1. Correlation between nitrogen content of the leaf and applied nitrogen doses

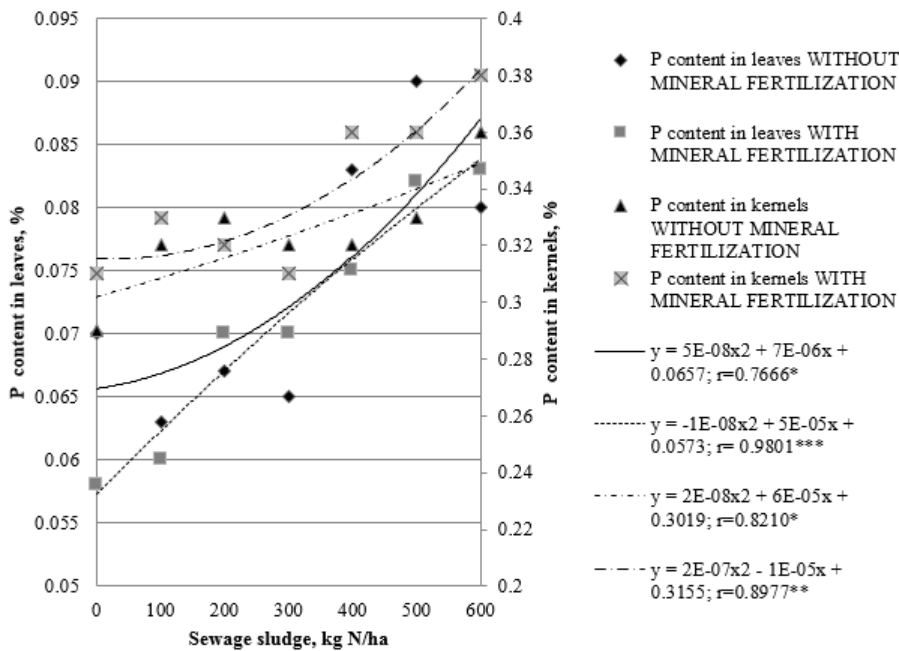


Fig. 2. Correlation between phosphorus content of the leaf and applied nitrogen doses

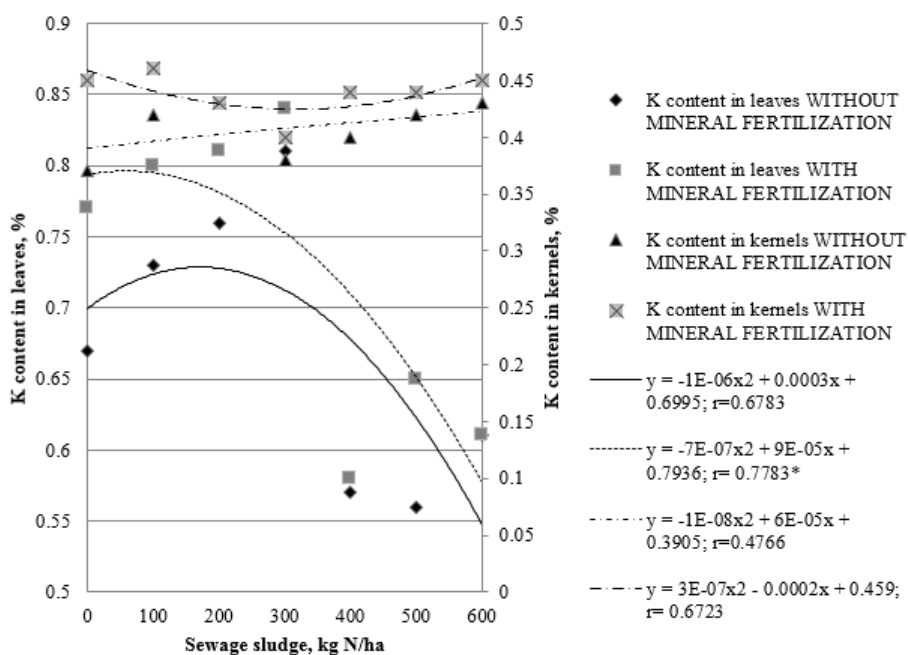


Fig. 3. Correlation between potassium content of the leaf and applied nitrogen doses

Sewage sludge		Ca			Mg		
		b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)
a <sub>1</sub>	0 kg N/ha	0.86	0.93	0.90a*	0.75	0.74	0.75a*
a <sub>2</sub>	100 kg N/ha	0.96	1.05	1.01ab	0.75	0.79	0.77a
a <sub>3</sub>	200 kg N/ha	1.12	1.24	1.18bc	0.95	0.98	0.97b
a <sub>4</sub>	300 kg N/ha	1.18	1.32	1.25cd	0.97	0.98	0.98b
a <sub>5</sub>	400 kg N/ha	1.24	1.38	1.31d	1.01	1.15	1.08bc
a <sub>6</sub>	500 kg N/ha	1.37	1.44	1.41d	1.31	1.25	1.28c
a <sub>7</sub>	600 kg N/ha	1.38	1.43	1.41d	1.15	1.25	1.20c
Av.(a)		1.16a*	1.26b	-	0.98a*	1.02a	-

**Table 4**  
INFLUENCE OF SEWAGE SLUDGE APPLICATION (WITHOUT/WITH MINERAL FERTILIZATION) ON Ca AND Mg CONTENTS IN LEAVES

b<sub>1</sub> - corresponds to N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> (without mineral fertilization); b<sub>2</sub> - corresponds to N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> (mineral fertilization); Av. - average  
\*Mean values accompanied by same letter (a or b) does not present significant differences (Tukey multiple comparison test - significance level 0.05)

Sewage sludge		Ca			Mg		
		b <sub>1</sub>	b <sub>2</sub>	Av.(b)	b <sub>1</sub>	b <sub>2</sub>	Av.(b)
a <sub>1</sub>	0 kg N/ha	0.05	0.04	0.05a*	0.25	0.27	0.26a*
a <sub>2</sub>	100 kg N/ha	0.05	0.05	0.05a	0.26	0.27	0.27a
a <sub>3</sub>	200 kg N/ha	0.01	0.02	0.02b	0.26	0.25	0.26a
a <sub>4</sub>	300 kg N/ha	0.01	0.02	0.02b	0.24	0.24	0.24a
a <sub>5</sub>	400 kg N/ha	0.01	0.01	0.01b	0.26	0.26	0.26a
a <sub>6</sub>	500 kg N/ha	0.02	0.02	0.02b	0.25	0.26	0.26a
a <sub>7</sub>	600 kg N/ha	0.01	0.01	0.01b	0.25	0.25	0.25a
Av.(a)		0.02a*	0.02a	-	0.25a*	0.26a	-

**Table 5**  
INFLUENCE OF SEWAGE SLUDGE APPLICATION (WITHOUT/WITH MINERAL FERTILIZATION) ON Ca AND Mg CONTENTS IN KERNELS

b<sub>1</sub> - corresponds to N<sub>0</sub>P<sub>0</sub>K<sub>0</sub> (without mineral fertilization); b<sub>2</sub> - corresponds to N<sub>100</sub>P<sub>100</sub>K<sub>100</sub> (mineral fertilization); Av. - average  
\*Mean values accompanied by same letter (a or b) does not present significant differences (Tukey multiple comparison test - significance level 0.05)

recorded in the rate equivalent to 200 kg N/ha. The lowest values of magnesium in the maize leaves were recorded in the unfertilized variants while the highest were obtained in the variants fertilized with sludge at a rate equivalent to 500 kg N/ha (table 4). Mineral fertilization or associated with organic fertilization resulted in no changes in the magnesium content of the maize leaves.

A previous study [11] evidenced that sewage sludge fertilization favors increasing of calcium and magnesium levels in sunflower stems and leaves, the highest values being observed in the case of a dose equivalent with 500 kg N/ha.

#### Influence of sewage sludge application on Ca and Mg contents in kernels

The calcium concentration in the maize kernels decreased significantly after the application of a sludge rate equivalent to 200 kg N/ha (table 5) and after the application of sewage sludge mixed with mineral fertilizers, in which case the decrease was not statistically assured.

Mineral fertilization led to no changes in the calcium concentration of the maize kernels. The differences between the variants fertilized with sludge in rates of 200 kg N/ha were not significant.

The results show that the fertilization system (based on sewage sludge only, on mineral fertilizers only, or on a mixture of both) led to no statistically significant change in the magnesium content of the maize kernels.

#### Correlation between different equivalents nitrogen doses from sludge applied and Ca and Mg uptake by plant

The content of Ca and Mg in maize leaves correlates very significant with nitrogen doses corresponding to the application of sludge in experimental variants with/without mineral fertilization.

In kernels the calcium content correlates distinctly significant with nitrogen doses from variants without mineral fertilization and significant for those with mineral fertilization, and a not-significant correlation indicate the magnesium content for all experimental variants and nitrogen doses applied (figs.4, 5).

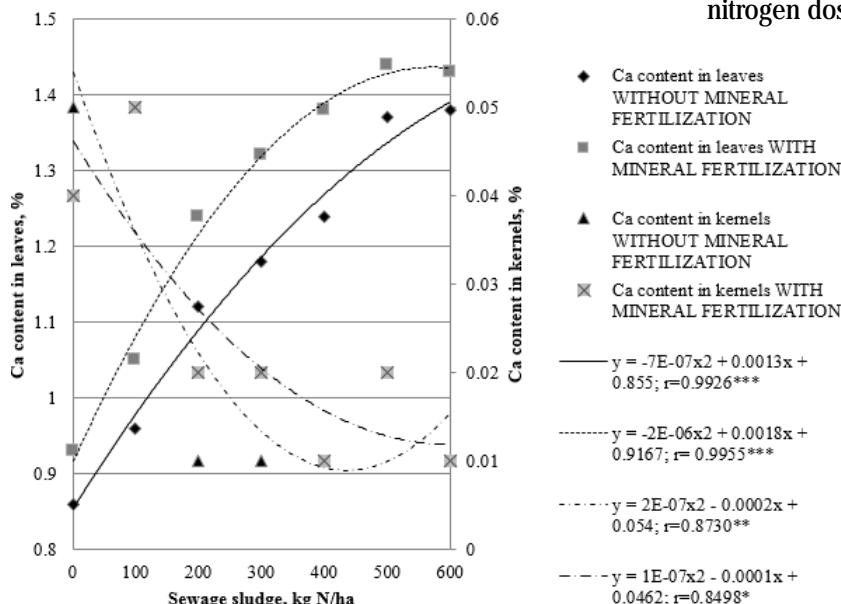


Fig. 4. Correlation between calcium content of the leaf and applied nitrogen doses

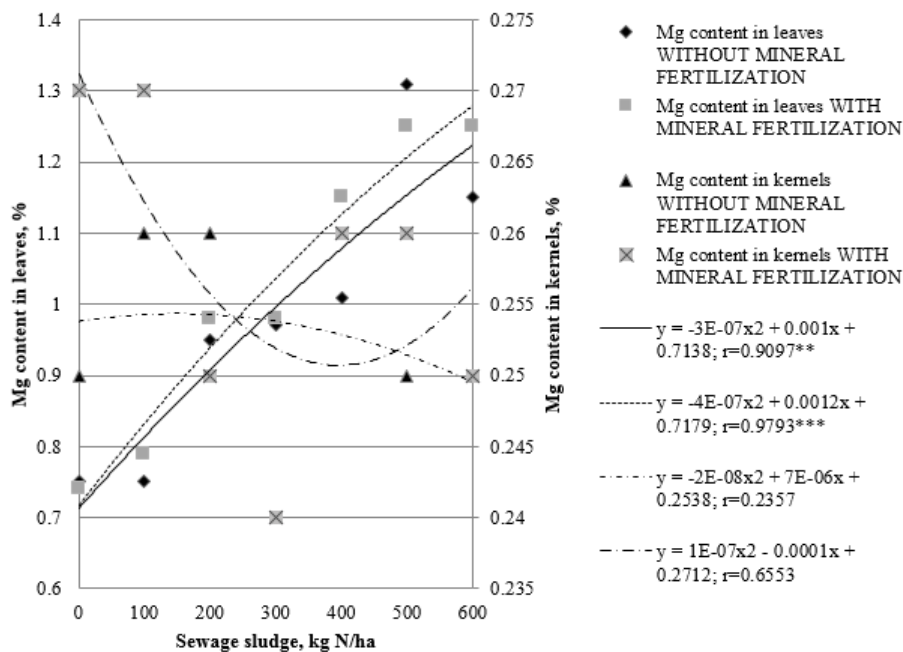


Fig. 5. Correlation between magnesium content of the leaf and applied nitrogen doses

## Conclusions

The research aim was to evaluate the effect of sewage sludge application in various doses (associated or not with mineral fertilizers) on growth of (*Zea mays* L.) by investigating the growth, yield and macroelements (N, P, K, Ca, Mg) accumulation. The obtained results led to the conclusions that are highlighted below.

Sewage sludge fertilization produces significant increase of maize yield and are evident starting with 200 kg N/ha rate, and the highest increases were recorded in the rate of 400 kg N/ ha.

Nitrogen and phosphorus contents in the maize kernels increased with sewage sludge loading, meanwhile in the case of potassium the data showed that there were no statistically significant changes in the potassium content of the maize kernels under the influence of sewage sludge fertilization.

The application of sewage sludge caused a significant increase of the calcium and magnesium contents in the maize leaves at equivalent rates higher than 200 kg N/ ha.

## References

1. BOZKURT, M.A., YARILGAC, T., YAZICI, A., Polish Journal of Environmental Studies, **19(2)**, 2010, p. 267.
2. CERNY, J., BALIK, J., KULHANEK, M., VASAK, F., PEKLOVA, L., SEDLAR, O., Plant Soil Environ., **58(2)**, 2012, p. 76.
3. WARMAN, P.R., TERMEER, W.C., Biores. Technol. **96**, 2005b, p.955.
4. AILINCAI, C., JIȚĂREANU, G., BUCUR, D., AILINCAI, D., Cercetări Agronomice în Moldova, XLV, **1(149)**, 2012, p.5.
5. AGHILINATEGH, N., HEMMAT, A., REZAINAJAD, Y., SADEGHI, M., XXXIII CIOSTA-CIGR V Conference, Reggio Calabria, Italy, Technology and management to ensure sustainable agriculture, agrosystems, forestry and safety, **2**, 2009, p.1059.

6. TSADILAS, C.D., MATSI, T., BARBAYIANNIS N., DIMOYIANNIS, D., Communications in Soil Science and Plant Analysis, **26(15-16)**, 1995, p.2603.
7. MIHALACHE, M., ILIE, L., MADJAR, R., Revue Roumaine de Chimie, **59(2)**, 2014, p.81.
8. CRIPPS, W., WINFREE, S.K., REAGAN, J.L., Soil Sci. Plant Anal., **23**, 1992, p.1705.
9. COSTICA, A., GERARD, J., DANIEL, B., DESPINA, A., J. Food, Agric. Environ. **5**, 2007, p.310.
10. CHATHA, T.H., HAYA, R., LATIF, I., Asian Journal of Plant Sciences, 2002, p.79.
11. MIHALACHE, M., ILIE, L., MADJAR, R.M., CALIN, C., VASILE SCAETEANU, G., Rev. Chim. (Bucharest), **66**, no. 7, 2015, p.951.
12. KONUSKAN, O., KONUSKAN, D.B., LEVAI, C.M., Rev. Chim. (Bucharest), **68**, no. 9, 2017, p. 2073
13. KAMAL, A.T.M.M., ISLAM, M.M., HOSSAIN, M.S., ULLAH, S.M., Bangladesh J. Sci. Res., **26(1&2)**, 2013, p.57.
14. MORERA, M.T., ECHEVERRIA, J., GARRIDO, J., Can. J. Soil Sci., **82**, 2002, p.433.
15. THEODORATES, P., MOIROU, A., XENIDIS, A., PASPALIARIS, I., Hazard. Mater., **B77**, 2000, p.177.
16. TSAKOU, A., ROULIA, M., CHRISTODOULAKIS, N.S., Bull. Environ. Contam. Toxicol., **68**, 2002, p.56.
17. DELGADO ARROYO, M.M., PORCEL COTS, M.A., MIRALLES DE IMPERIAL HORNEDO, R., BELTRAN RODRIGUES, E.M., BERINGOLA BERINGOLA, L., MARTIN SANCHEZ, J.V., Rev. Int. Contam. Ambient., **18(3)**, 2002, p.147.
18. FAGERIA, N.K., BALIGAR, V., JONES, C.A., Growth and mineral nutrition of field crops, Third edition. CRC Press, Taylor and Francis Group, 2011.
19. ILIE, L., VASILE SCAETEANU, G., MIHALACHE, M., MADJAR, M., CALIN, C., Rev. Chim. (Bucharest), **65**, no.12, 2014, p.1485.
20. SINGH, R.P., AGRAWAL, M., Chemosphere, **67**, 2007, p.2229.
21. FAO 1998. World Reference Base for Soil Resources, by ISSS- ISRIC-FAO. World Soil Resources Report, No. 84, Rome.
22. GONDEK, K., J. Elementol **15(1)**, 2010, p.65.

Manuscript received: 14.07.2017