Influence of Fertilization Systems on Physical and Chemical Properties of the Soil

OANA MARIA MUSCALU (PLESCAN)[1,2], VALENTIN NEDEFF[1,3], ALEXANDRA DANA CHITIMUS[1]*, IOAN GABRIEL SANDU[4,5], ELENA PARTAL[6], EMILIAN MOSNEGUTU[1], ION SANDU[5,7]*, DRAGOS IOAN RUSU[1]

[1] Vasile Alecsandri University of Bacau, Department of Environmental Engineering and Mechanical Engineering, 157 Calea Marasesti, 600115, Bacau , Romania

[2] Romanian Waters - National Administration of Siret Basin, 1 Cuza Voda Str., 600274, Bacau, Romania

[3] Gheorghe Ionescu Sisesti, Academy of Agricultural and Forestry Sciences Bucharest, 61 Marasti Blvd., 011464, Bucharest, Romania

[4] Gheorghe Asachi Technical University of Iasi, Faculty of Material Sciences and Engineering, 69 Dumitru Mangeron Str., 700050, Iasi, Romania

[5] Romanian Inventors Forum, 3 Sf. Petru Movila St., Bl. L11, III/3, 700089, Iasi, Romania

[6] National Agricultural Research and Development Institute of Fundulea, Calarasi, 1 Nicolae Titulescu Str., 915200, Fundulea, Romania

[7] Alexandru Ioan Cuza University of Iasi, ARHEOINVEST Interdisciplinary Platform, 22 Carol I Blvd., 700506, Iasi, Romania

The purpose of this research have been to determine the influence of soil fertilizations systems (fertilization with: nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure) on the physical properties (penetration hardness) and chemical properties (humidity, metals) of the soil. The experiments have been carried out in the experimental field of National Agricultural Research and Development Institute -Fundulea, Romania, for a wheat monoculture. The lowest values of the metal content in soil (nickel, copper, zinc, arsenic, lead) have been recorded for wheat experimental variant -fertilized with N90P75 kg/ha (a_1b_4), and the highest content have been recorded for manganese (766 mg/kg dry matter), and for the wheat experimental variant a_1b_4, respectively (wheat-fertilized with N90P75 kg/ha active matter), working depth 0-15 cm.

Keywords: nitrogen, phosphorus, farmyard manure, wheat, monoculture

Natural (organic) fertilizers are a source of nutritive mineral elements for plants, thus contributing to the improvement of physical and biological features of the soil. Farmyard manure has a complex effect on plants and soil. It is applied in summer and autumn and it is embedded in soil by ploughing. Higher doses are recommended for low fertility soils and on irrigated surfaces, for intensive culture [1-10].

Plant growth and development processes require large quantities of nutritive elements, extracted from soil through the roots. Consumption balance is possible by applying fertilizers, avoiding the lowering of soil's productive potential [11-26].

The purpose of this research has been to determine the influence of soil fertilizations systems on the physical properties (penetration hardness) and chemical properties (humidity, metals: chrome, manganese, nickel, copper, zinc, arsenic, lead, cadmium).

Experimental part

When choosing the sampling point in order to determine the heavy metal content and physical properties of the soil, the research team took into account the topo-pedological base of the agrochemical cropping plots, updated with all necessary elements to identify and locate the plots.

The study has been carried out in the experimental field of National Agricultural Research and Development Institute- Fundulea, Romania, for a wheat monoculture. The researches at INCDA have been carried out following a two-factor experience, stationary and multiannual, mounted in 1968 and up to date, with reference to emphasizing the differentiation of soil's properties as an effect of fertilization sequence, i.e:

- nitrogen (90 kg N/ha active matter – active matter);
- phosphorous (75 kg P/ha active matter);
- nitrogen and phosphorous (N90P75 kg/ha active matter);
- farmyard manure.

The experimental variants carried out at INCDA have been of the following type (fig. 1, table 1):

- wheat monoculture (Factor a): a_1.
- fertilization with (Factor b):

-unfertilized: b_1 (N0P0 kg/ha active matter);
-nitrogen - 90kg N/ha active matter: b_2;
-phosphorous - 75 kg P/ha active matter: b_3;
-nitrogen and phosphorous - N90P75 kg/ha active matter: b_4;
-farmyard manure: b_5.

Table 1
SOIL CROP-ROTATION FOR THE PERIOD 2006-2016, I.E. FOR WHEAT CULTURE

YEAR	FACTOR
	a_1
2006÷2016	wheat

The soil samples have been taken on two depths:
- 0 - 15 cm;
- 15 - 30 cm.

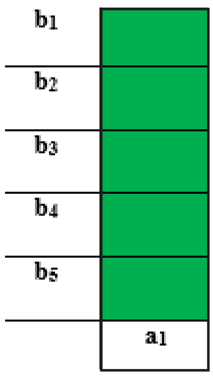

Fig. 1. Experimental variant by INCDA

* email: dana.chitimus@ub.ro; ion.sandu@uaic.ro

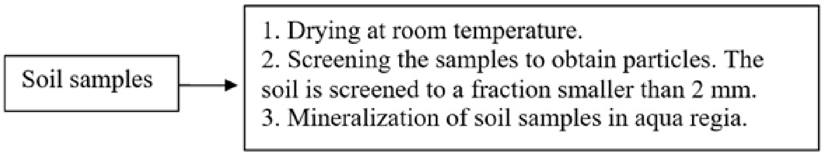

Fig. 2. Soil samples preparation methods to determine heavy metals through inductively coupled plasma mass spectrometry, and atomic absorption spectrometry respectively [27-30].

The soil samples have been taken in 2016. All soil samples have been collected as a composite form each parcel after wheat harvesting.

Figure 2 shows soil sampling method used to determine the soil heavy metal content.

Moreover, in the filed have been determined:

- soil penetration hardness, by the penetrologger (fig. 3);
- soil humidity, by the in situ direct reading moisture sensor (fig. 4).

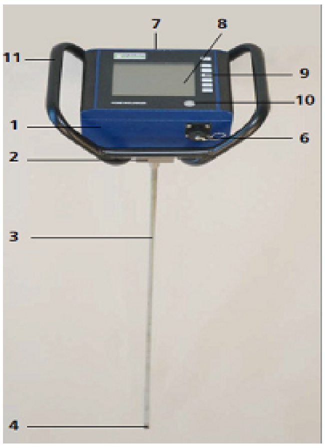

Fig. 3. Penetrologger: 1 - waterproof case; 2 - impact attenuator; 3 - draw bar; 4 - cone; 5 - reference depth measuring plate; 6 - communication port; 7 - GPS antenna; 8 - LCD screen; 9 - control panel; 10 - level; 11 - handgrips [30]

Fig. 4. Moisture sensor [30]

Experiments have been carried out for the content of eight metals in the soil: chrome, manganese, nickel, copper, arsenic, lead, cadmium.

The metal content in the soil samples has been determined by using inductively coupled plasma mass spectrometer (ICP-MS) [17], Agilent 7500cx ICP-MS version and an atomic absorption spectrometer (AAS), ZEENIT AAS version. Through the inductively coupled plasma mass spectrometry, the following metals have been detected: chrome, nickel, copper, arsenic, lead, and cadmium. Through atomic absorption spectrometry, zinc and manganese content has been detected [28, 29].

Results and discussions

Tables 2 and 3 show the experimentally determined values for the soil samples taken on the unfertilized wheat parcel (control sample) for eight heavy metal and for the in physical properties measured in situ.

Table 3 shows the experimentally determined values for eight metals in soil in which a wheat monoculture has been embedded, with fertilization sequence in 2016.

The *manganese* content value (fig. 5) registered in the nitrogen fertilized parcel (90 kg N/ha) was 9.02 % lower than the value registered in the unfertilized soil parcel for the 0-15 cm depth, respectively by 14.79 % lower than the control sample for the 15-30 cm depth.

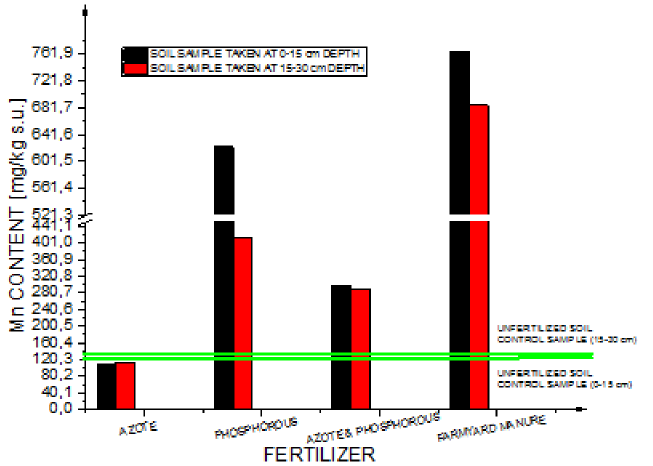

Fig. 5. Manganese content in soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure, for the 0-15 cm and 15-30 cm depths respectively

Table 2
EXPERIMENTALLY DETERMINED VALUES FOR THE EIGHT METALS IN THE UNFERTILIZED SOIL PARCEL (CONTROL SAMPLE)

Depth [cm]	Cr	Mn	Ni	Cu	Zn	As	Pb	Cd
	[mg/kg s.u.]							
0-15	LOQ*	120.30	25.44	14.36	19.65	7.79	13.95	0.13
15-30	LOQ*	133.90	36.33	22.15	50.55	10.63	18.15	0.29

* Values below the Limit of Quantitation (LOQ) of the method.

Table 3
EXPERIMENTALLY DETERMINED VALUES FOR HUMIDITY AND RESISTANCE TO PENETRATION HARDNESS IN THE UNFERTILIZED SOIL PARCEL (CONTROL SAMPLE)

Depth [cm]	Humidity [%]	Resistance to penetration [MPa]
0-15	4	3.00
15-30	7	2.70

In the case of the phosphorous fertilized parcel (75 kg P/ha) the soil manganese content was 517.87 % higher than the value registered on the unfertilized soil parcel for the 0-15 cm depth, respectively 309.55 % higher for the 15-30 cm depth;

The *nickel* content value (fig. 6) on the nitrogen fertilized parcel was 112.22 % higher than the control sample value for the 0-15 cm depth. For the 15-30 cm depth the nickel content was 77.73 % of the control sample value.

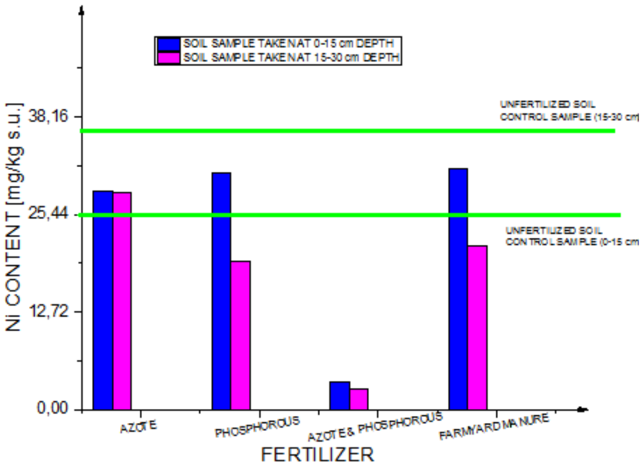

Fig. 6. Nickel content on soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure for the 0-15 cm and 15-30 cm depths

For the soil parcel fertilized with 75 kg P/ha (b_3) factor, the nickel content was 121.14 % higher than the control sample value, for the 0-15 cm depth, respectively 46.62 % lower than the control sample value for the 15-30 cm depth.

The *nickel* content for the experimental wheat variants -fertilized with nitrogen and phosphorous N90P75 kg/ha ($a_1b_{4)}$ and wheat-fertilized with farmyard manure (a_1b_5) was:

- wheat - fertilization with nitrogen and phosphorous N90P75 kg/ha ($a_1b_{4)}$:

Ï% 0-15 cm: 14.46 % of the soil control sample value;

Ï% 15-30 cm: 7.37 % of the soil control sample value;

- wheat- fertilization with farmyard manure (a_1b_5):

Ï% 0-15 cm: 123.11 % lower than the valued registered in the soil sample with no fertilization sequence;

Ï% 15-30 cm: 41.34 % lower than the valued registered in the soil sample with no fertilization sequence.

The *copper* content value (fig. 7) registered for the soil parcel fertilized with nitrogen was 109.22 % higher than the value registered for the unfertilized soil parcel for the 0-15 cm depth, respectively 30.79 % lower than the control sample, for the 15-30 cm depth.

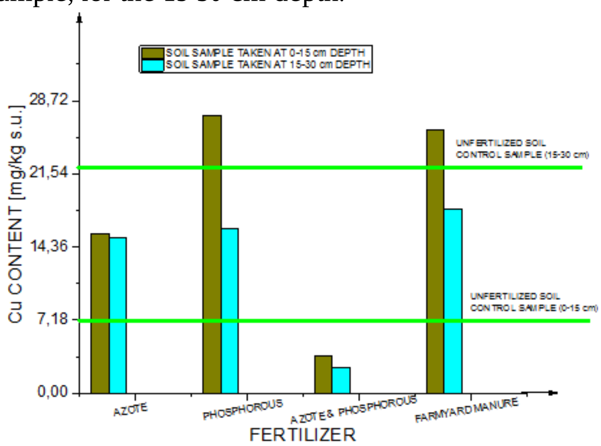

Fig. 7. Copper content on soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure for the 0-15 cm and 15-30 cm depths

In the case of the phosphorous fertilized parcel, the copper content was 190.18 % higher than the value registered for the unfertilized soil parcel for the 0-15 cm depth, respectively 27.31 % lower than the control sample, for the 15-30 cm depth.

The *copper* content for the experimental wheat variants -fertilized with nitrogen and phosphorous N90P75 kg/ha (a_1b_4) was:

- 0-15 cm: 25.833 % of the soil control sample value;
- 15-30 cm: 11.33 % of the soil control sample value.

For the soil parcel fertilized with farmyard manure (b_5) the copper content was 180.36 % higher than the control sample value, for the 0-15 cm depth, respectively 18.64 % lower than the control sample, for the 15-30 cm depth.

Zinc content (fig. 8) for the analysed experimental variants was:

- wheat – fertilization with nitrogen - 90 kg N/ha (a_1b_2):

Ï% 0-15 cm: 114.24 % higher than the valued registered in the soil sample with no fertilization sequence;

Ï% 15-30 cm: 36.69 % of the soil control sample value;

- wheat - fertilization with phosphorous -75 kg P/ha (a_1b_3):

Ï% 0-15 cm: cu 232.41 % higher than the valued registered in the soil sample with no fertilization sequence;

Ï% 15-30 cm: cu 46.27 % lower than the valued registered in the soil sample with no fertilization sequence.

- wheat - fertilization with nitrogen and phosphorous - N90P75 kg/ha (a_1b_4):

Ï% 0-15 cm: 17.4 % of the soil control sample value;

Ï%15-30 cm: 6.76 % of the soil control sample value;

- wheat-fertilization with farmyard manure (a_1b_5):

Ï% 0-15 cm: cu 236.74 % higher than the valued registered in the soil sample with no fertilization sequence;

Ï% 15-30 cm: cu 35.98 % lower than the valued registered in the soil sample with no fertilization sequence.

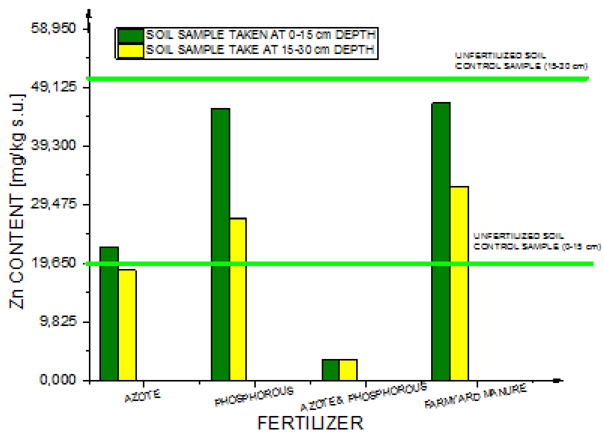

Fig. 8. Zinc content on soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure for the 0-15 cm and 15-30 cm depths

Arsenic content value (fig. 9) registered for the soil parcel fertilized with nitrogen was 129.65 % higher than the control sample value for the 0-15 cm depth. For the 15-30 cm depth the *nickel* content was 83.63 % of the control sample value.

For the soil parcel fertilized with phosphorous (b_3), the arsenic content was 125.93 % higher than the control sample value for the 0-15 cm depth, respectively 32.07 % lower than the control sample, for the 15-30 cm depth.

The arsenic content for the experimental variants wheat -fertilization with nitrogen, and phosphorous N90P75 kg/ha (a_1b_4) and wheat- fertilization with farmyard manure (a_1b_5) was:

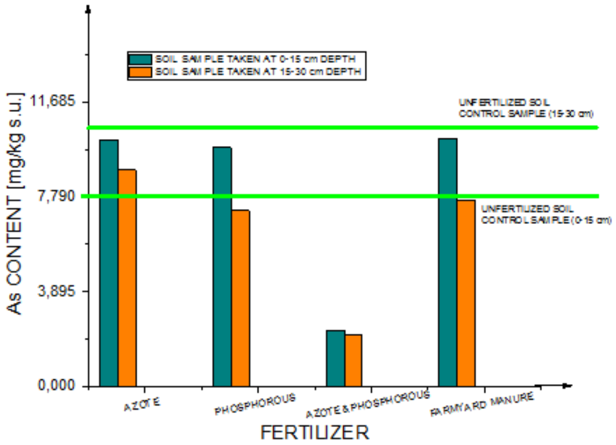

Fig. 9. Arsenic content on soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure for the 0-15 cm and 15-30 cm depths

- wheat- fertilization with nitrogen and phosphorous - N90P75 kg/ha (a_1b_4):
Ï% 0-15 cm: 29.78 % of the soil control sample value;
Ï% 15-30 cm: 19.94 % of the soil control sample value;
- wheat- fertilization with farmyard manure (a_1b_5):
Ï% 0-15 cm: 129.65 % higher than the valued registered in the soil sample with no fertilization sequence;
Ï% 15-30 cm: cu 27.93 % lower than the valued registered in the soil sample with no fertilization sequence.

The *lead* content (fig. 10) registered for the soil parcel fertilized with nitrogen was (90 kg N/ha) was 116.34 % higher than the value registered for the unfertilized soil parcel for the 0-15 cm depth, respectively 151.73 % higher than the control sample, for the 15-30 cm depth.

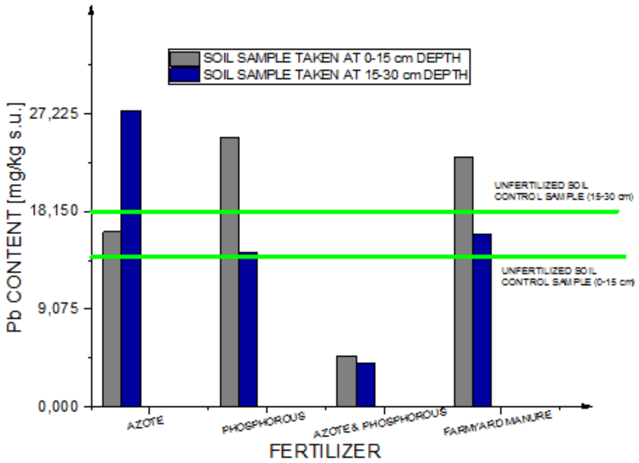

Fig. 10. Lead content on soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure for the 0-15 cm and 15-30 cm depths

In the case of the soil parcel fertilized with phosphorous (75 kg P/ha) the soil lead content was 179.21 % higher than the value registered for the unfertilized soil parcel for the 0-15 cm depth, respectively 21.15 % lower than the control sample, for the 15-30 cm depth.

For the soil parcel fertilized with nitrogen and phosphorous (b_4), the lead content was 33.62 % of the soil control sample value, for the 0-15 cm depth, respectively 22.14 % of the soil control sample value for the 15-30 cm depth.

For the soil parcel fertilized with farmyard manure (b_5), the lead content was 166.52 % higher than the value registered for in the soil control sample, for the 0-15 cm depth, respectively 11.95 % lower than the value registered for in the soil control sample, for the15-30 cm depth.

Cadmium content (fig. 11) for the analysed experimental variants was:
- wheat- fertilization with nitrogen - 90kg N/ha (a_1b_2):
Ï% 0-15 cm: 46.15 % of the soil control sample value;
Ï% 15-30 cm: 62.06 % of the soil control sample value;
- wheat- fertilization with phosphorous -75 kg P/ha (a_1b_3):
Ï% 0-15 cm: 223.07 % higher than the valued registered in the soil sample with no fertilization sequence;
Ï% 15-30 cm: 96.55 % lower than the valued registered in the soil sample with no fertilization sequence.
- wheat - fertilization with nitrogen and phosphorous - N90P75 kg/ha (a_1b_4):
Ï% 0-15 cm: 1184.61 % higher than the valued registered in the soil sample with no fertilization sequence;
Ï% 15-30 cm: 351.72 % higher than the valued registered in the soil sample with no fertilization sequence;
- wheat- fertilization with farmyard manure (a_1b_5):
Ï% 0-15 cm: 7.69 % of the soil control sample value;
Ï% 15-30 cm: 6.89 % of the soil control sample value.

In the case of the chrome, the values registered for each fertilization sequence have been below the Limit of Quantitation.

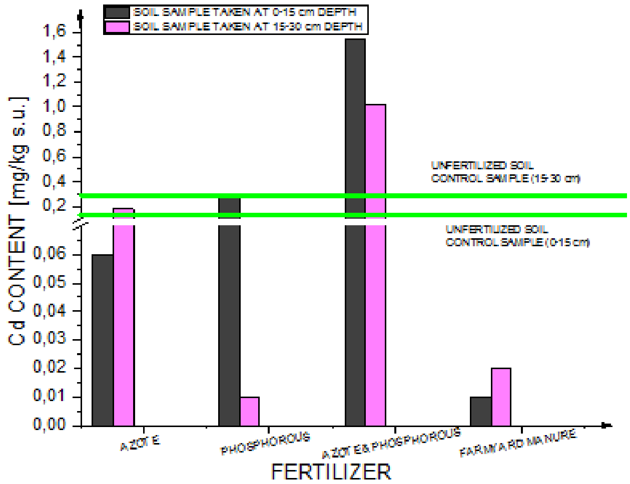

Fig. 11. Cadmium content on soil parcels fertilized with nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure for the 0-15 cm and 15-30 cm depths.

Table 4
EXPERIMENTALLY DETERMINED VALUES FOR HUMIDITY AND RESISTENCE TO PENETRATION FOR SOIL PARCELS WHERE A FERTILIZATION SEQUENCE HAS BEEN APPLIED

Experimental value	Depth [cm]	Humidity [%]	Resistence to penetration [MPa]
a_1b_2	0-15	5	3.70
	15-30	5	2.80
a_1b_3	0-15	3	3.60
	15-30	8	3.10
a_1b_4	0-15	3	2.90
	15-30	8	3.10
a_1b_5	0-15	2	2.70
	15-30	9	2.80

Soil humidity has been registered with values between 2 and 9%.

Soil *humidity* value (table 4) for the soil parcel where a fertilization sequence has been applied was 125 % higher than the value registered on unfertilized soil parcel for the 0-15 cm depth.

For the 15-30 cm working depth, the soil humidity lowered by 28.57 % compared to the soil control sample.

For the experimental wheat variants - fertilization with phosphorous - 75 kg P/ha (a_1b_3) and wheat - fertilization with nitrogen and phosphorous - N90P75 kg/ha (a_1b_4), soil humidity for the 10-15 cm working depth was 25 % lower than the soil control sample, and for the 15-30 cm depth it was 114.28 % higher than the soil control sample.

The lowest humidity value (compared to all the other experimental variants) has been registered for the experimental variant wheat - fertilization with farmyard manure (a_1b_5), for the 0-15 cm working depths, respectively 50 % of the soil control sample value.

In the case of the experimental variant wheat - fertilization with farmyard manure (a_1b_5), 15-30 cm depth, the highest humidity value has been registered, compared to all the other experimental variants (128. 57 % higher than the control sample value.)

Resistance to penetration values varied between 2.70 ÷ 3.70 MPa, meaning that the soil is in the ***light soil*** category.

Soil's resistance to penetration (table 4) for the analysed experimental variants was:

- wheat- fertilization with nitrogen - 90kg N/ha (a_1b_2):

Ï% 0-15 cm: 123.33 % higher than the valued registered in the soil sample with no fertilization sequence;

Ï% 15-30 cm: 103.7 % higher than the valued registered in the soil sample with no fertilization sequence;

- wheat- fertilization with phosphorous -75 kg P/ha (a_1b_3):

Ï% 0-15 cm: 120 % higher than the valued registered in the soil sample with no fertilization sequence;

Ï% 15-30 cm: 114.81 % higher than the valued registered in the soil sample with no fertilization sequence.

- wheat – fertilization with nitrogen and phosphorous - N90P75 kg/ha (a_1b_4):

Ï% 0-15 cm: 3.33 % lower than the valued registered in the soil sample with no fertilization sequence;

Ï%15-30 cm: 114.81 %;

- wheat- fertilization with farmyard manure (a_1b_5):

Ï% 0-15 cm: 90 % of the higher than the valued registered in the soil sample with no fertilization sequence soil control sample value;

Ï% 15-30 cm: 103.7 % higher than the valued registered in the soil sample with no fertilization sequence.

The extremely high values of the soil's manganese content are due to its high capacity of metal stabilization by the *Triticum aestivum* species (wheat) through the phyto-stabilization process.

The lowest metal content values have been registered for the fertilization with nitrogen and phosphorous (b_4), for the 15-30 cm working depth, except for the cadmium, where the registered value was much higher than the control sample.

Conclusions

Modern, intensive, high-yielding farming exerts a considerable stress on soil. The numerous crops, diversification of cultures, with or without taking into account the crop-rotation, severe modification of aero-hydric regime through irrigation and drainage, increment of ploughing depth, intense traffic very often with high heavy vehicles, fertilization and other technological measures, strictly necessary to obtain a high productivity, exert positive effects but sometimes also negative effects on soil's properties [11].

In the case of the soil parcel fertilized with farmyard manure (a_1b_5) for the 0-15 cm working depth, the lowest manganese content was registered, due to *Triticum aestivum*'s capacity to stabilize metals in soil.

The lowest metal contents in soil (nickel, copper, zinc, arsenic, lead) have been registered for the experimental variant wheat – fertilization with nitrogen and phosphorous - N90P75 kg/ha (a_1b_4), both for 0-15 cm and for 15-30 cm working depths.

Soil's metal contents variations are mainly due to the applied fertilizers sequence (nitrogen, phosphorous, nitrogen and phosphorous, farmyard manure), to *Triticum aestivum*'s capacity to stabilize/assimilate metals in/from soil, as well as to climatic conditions in 2016.

References

1.SANGAR, K., RIFAT, H., MUHAMMAD, SHAKIR, F., QAISER, H., NOSHEN A.A., Advances in Crop Science and Technology, **6,** no. 1, 2017, p. 328.

2.UZOMA, K.C., INOUE, M., ANDRY, H., FUJIMAKI, H., ZAHOOR, A., NISHIHARA, E., Soil Use and Management, **27**, 2011, p. 205.

3.YANG, R., SU, Y., WANG, T., YANG, Q., Journal of Integrative Agriculture, **15**, no. 3, 2017, p. 658.

4.IRIMIA, O., NEDEFF, V., PANAINTE LEHADUS, M., TOMOZEI, C., Journal of Engineering Studies and Research, **22**, no. 1, 2016, p. 64.

5.DINU, C., UNGUREANU, E.M., VASILE, G.G., KIM, L., IONESCU, I., ENE, C., SIMION, M., Rev. Chim.(Bucharest), **69**, no. 1, 2018, p. 14.

6.MASU, S., COJOCARIU, L., GRECU, E., MORARIU, F., BORDEAN, F.D., HORABLAGA, M., NITA, L., NITA, S., Rev. Chim.(Bucharest), **69**, no. 5, 2018, p. 1110.

7.CHITIMUS, A.D., NEDEFF, V., MOSNEGUTU, E.F. PANAINTE M., Environmental Engineering and Management Journal, **11**, no. 12, 2012, p. 2161.

8.TURCU, M., BARSAN, N., IRIMIA, O., JOITA, I., BELCIU, M., Environmental Engineering and Management Journal, **13**, no. 7, 2014, p. 1751.

9.SIFOLO, S.C, JEROME, E.T., KOUADIO, I.K., BARSAN, N., NEDEFF, V., ZORO, I.A., International Journal of Agronomy and Agricultural Research, **8**, no. 3, 2016, p. 26.

10. BELCIU, M.C., MOSNEGUTU, E.F., NEDEFF, V., CHITIMUS, A.D., BARSAN, N., FIORE, S., Environmental Engineering and Management Journal, **15**, no. 3, p. 2057.

11.CHITIMUS, A.D., Studies and researches on the influence of mechanical and physical properties of soil in self-cleaning and cleaning, PhD Thesis, Vasile Alecsandri University of Bacau, Romania, 2011.

12.CHITIMUS, A.D., NEDEFF, V., MOSNEGUTU, E., LAZAR, G., Soil Cleaning Techniques (in Romanian), Ed. Alma Mater, Bacau, 2012, p. 51.

13.CHITIMUS, A.D., NEDEFF, V., LAZAR, G., Journal of Engineering Studies and Research, **17**, no. 4, 2011, p. 24.

14.CHITIMUS, A.D., RADU, C., NEDEFF, V., MOSNEGUTU, E., BARSAN, N., Scientific Study & Research Chemistry & Chemical Engineering, Biotechnology, Food Industry, 17, no. 4, 2016, p. 381.

15.CHITIMUS, A.D., BARSAN, N., NEDEFF, V., MOSNEGUTU, E., MUSCALU (PLESCAN), O., Studies and research concerning the influence of liquid pollutants' leaching speed in the soil on the process of cleaning and self-cleaning, 17th International Multidisciplinary Scientific GeoConference SGEM 2017, **17**, no. 51, 2017, pp. 859-866.

16.CLEMENS, S., PALMGREN, M.G., KRAMER, U., Plant Science, **7**, 2002, p. 309.

17.GREGER, M., Metal availability, uptake, transport and accumulation in plants, in Heavy Metal Stress in Plants – from biomolecules to ecosystems, Springer Heidelberg, 2004, pp. 1-27.

18.RADU, C., CHITIMUS, A.D., TURCU, M., ARDELEANU, G., BELCIU, M., Environmental Engineering and Management Journal, **13**, no. 7, 2014, p. 1687.
19.RADU, C., NEDEFF, V., CHITIMUS, A.D., Journal of Engineering Studies and Research, **19**, no. 2, 2013, p. 89.
20.SENILA, M., LEVEI, E., MICLEAN, M., SENILA, L., STEFANESCU, L., MARGINEAN, S., OZUNU, A., ROMAN, C., Environmental Engineering and Management Journal, **10**, 2011, p. 59.
21.PAPADATU, C.P., BORDEI, M., ROMANESCU, G., SANDU, I., Rev. Chim. (Bucharest), **67,** no. 9, 2016, p. 1728.
22. SAMREEN, S., INAM, A., KHAN, A.A., International Journal of Conservation Science, **8,** no. 4, 2017, p. 695.
23. BURTEA, M.C., SANDU, I.G., CIOROMELE, G.A., BORDEI, M., CIUREA, A., ROMANESCU, G., Rev. Chim. (Bucharest), **66,** no. 5, 2015, p. 621.
24. DAIRO, O.S., SOYELU, O.J., International Journal of Conservation Science, **8,** no. 3, 2017, p. 509.
25. UNGUREANU, G., IGNAT, G., VINTU, C.R., DIACONU, C.D., SANDU, I.G., Rev. Chim. (Bucharest), **68,** no. 3, 2017, p. 570.
26. VASILACHE, V., CRETU, M.A., PASCU, L.F., RISCA, M., CIORNEA, E., MAXIM, C., SANDU, I.G., CIOBANU, C.I., International Journal of Conservation Science, **6,** no. 1, 2015, p. 93.
27. *** ICP-MS System, 7500cx ICP-MS, Agilent, Operating Manual, 2007.
28.*** Atomic absorption spectrometry (AAS) ZEEnit 700, Operating Manual, 2009.
29.***SR EN ISO 17294-2:2016 Water quality - Application of inductively coupled plasma mass spectrometry (ICP-MS) - Part 2: Determination of selected elements including uranium isotopes.
30.*** Penetrologger, Operating instructions, 2010.

Manuscript received: 19.02.2018