Scientific Papers. Series A. Agronomy, Vol. LXI, No. 2, 2018
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

AGROCHEMICAL CHARACTERISTICS AND FERTILITY OF THE ALLUVIAL IRRIGATED SOILS OF UKRAINE AND MOLDOVA

Marina ZAKHAROVA[1], Tamara LEAH[2], Sveatoslav BALIUK[1], Valerian CERBARI[2], Oleksandr NOSONENKO[1]

[1]National Scientific Center „Institute for Soil Science and Agrochemistry Research Named after O.N. Sokolovsky”, 4 Chaikovska Street, Kharkov, 61024, Ukraine
[2]Institute of Soil Science, Agrochemistry and Soil Protection „Nicolae Dimo”, 100 Ialoveni Street, Chisinau, 2070, Republic of Moldova

Corresponding author email: tamaraleah09@gmail.com

Abstract

The parameters of the agrochemical state and fertility of alluvial-meadow soils of the Dnieper and Dniester rivers have been studied. Irrigation of soils of the floodplain Dnieper river is characterized by a high degree of fertility of the 0-20 cm layer: a high content of humus, nitrogen, phosphorus and potassium (according to the National Standards of Ukraine). In the profile distribution of humus content in the non-irrigated soil, there are two peaks: the sod and the buried humus horizon. The content of nutrients from the sod to depth on the profile of the non-irrigated soil is sharply reduced. Alluvial irrigated soils in the Dniester meadow are characterized by low humus content in dependence on the soil clay texture, high content of mobile phosphorus and exchangeable potassium in the arable layer. In the deeper horizons of the all studied soils, the content of nutrients and humus sharply decreases. To increase the fertility of irrigated agricultural soils it is necessary to increase the flow of organic matter into the arable layer by using them under multi-annual grasses.

***Key words**: alluvial soil, irrigated soil, fertility, meadow, profile.*

INTRODUCTION

The river beds (meadow) are the geomorphological bases of the drainage basins. In the process of evolution, the meadows are subjected to different processes, conditioned by the river regime and the hydrographical processes within the drainage basin. The processes of meadow formation are very complicated and lead to the creation of large variables of alluvial soils (alluvisoils) on different segments of meadows. The variability of alluvisoils is complicated not only by the alluvial processes, but also by the local peculiarities of the water regime of the meadow, the quality of the groundwaters etc. All these local and dynamic particularities contribute to the formation of alluvisoils variability in the river beds. Depending on the length of the river and the dimensions of the meadow, alluvisoils with different morpho-logical structures, substantial composition, hydrological regimes, salinization degrees are formed on different segments (Думих, 2016).

Alluvial soils belong to the class of soils, their composition and properties being subjected and conditioned by different current processes. Alluvial soils are intrazonal formations, as the transitional river beds pass through different natural areas and pedogeographic units (Ursu et al., 2012).

In recent years, the United Nations Food and Agriculture Organization (FAO) has set the soils as world's most important priority for food security (Revised World Soil Charter ..., 2015).

Under conditions of soil cover degradation and global warming, food security can be ensured only by expanding of irrigated soils.

Irrigation is a powerful impact factor on the soils. The introduction of additional moisture in the soil determines the transformation of the organic and mineral constituents of soils (Балюк, 2009). It is known that the direction and intensity of soil processes is determined by the quality of irrigation water, climatic and hydrogeological conditions of the regions, relief, buffer properties of soils, irrigation technology and crop culture (Балюк, 2013).

The most suitable areas for development of irrigated agriculture are fields and meadows with alluvial soils non-salinzated and non-solonetzizated.

On the territory of Moldova, within the agricultural land, the alluvial soils occupy the area of about 117 thousand hectares and are the main object for the development of irrigated agriculture. In this case, a major interest for the extension of the irrigated agriculture is the alluvial soils from the Dniester meadow.

Among the irrigated lands in Ukraine there are about 350 thousand hectares of saline, of which 70-100 thousand hectares of secondarily saline soils.

The area of solonetzic soils is 2.8 million hectares (mainly within the Steppe), about 2/3 of them are ruined, and about 0.8 million hectares are irrigated (Балюк, 2012).

The alluvisoils, due to the extremely different conditions regarding the duration of the solification, the climate of the area, the origin of the fluvial deposits, their texture and composition, the depth and mineralization of the groundwater, are characterized by a great variation of properties and composition. Irrigation acts differently on the quality of alluvial soil varieties.

The aim of the research is to identify changes in agrochemical properties and fertility of alluvial soils in the Dniester and Dnieper meadows influenced by irrigation.

MATERIALS AND METHODS

Field survey of irrigated lands of the lower reaches of the Dnieper (Ukraine, Kherson region) and Dniester (Moldova, Kaushani district) was conducted using the analogy-key method on the polygons.

In the investigation area, the key sites and polygons have been laid on irrigated and non-irrigated soils. Within the sites laid down by the soil section and wells to the depth of groundwater (1-2 m). Mixed soil samples from each genetic horizon were selected from each section and well.

Selection, preparation for analysis and preliminary processing of soil samples of the lower reaches of the Dnieper and Dniester, subjected to agrochemical analysis, were carried out according to the normative documents and methods existing in Ukraine and Moldova (Soils quality: 2002, 2004a, 2004b, 2007a, 2007b).

The investigated irrigated soil (Ukraine) is alluvial sod soil, used for a long time in organic farming, drip irrigation (20 years) and vegetable crop rotation (Figure 1). Non-irrigated variant is alluvial meadow soil (virgin), used in agricultural production as pasture.

Figure 1. Alluvial irrigated soil of Lower Dnieper meadow

In the profile of irrigated soil, horizons have been identified: as arable, transitional and rock-wet, loose, sandy. Groundwater-deeper than 1 m. In non-irrigated soil, another structure of the soil profile was noted - horizons were distinguished: sod, humus gleyied, transitional, transitional gleyeid, rock. From the depth of 9 cm the soil is moist, and from 85 cm and deeper-groundwater.

Investigated irrigated alluvisoils of Moldova are widespread in the meadow beneath the terraces of the Lower Dniester on the territory

of Kopanca commune in Kausheni district, and as well in other communes in the southern districts of Moldova, especially in the last 30 years. At present, irrigation of alluvisoils on the territory of Kopanca commune is carried out by sprinkling with a Fregat type irrigation plant.
The researched territory, until the irrigation landscaping works were done, was swamping and often affected by the overflowing of the Dniester river. In 1985 a dam was built, which avoids the overflowing of this land and an efficient drainage-drying system of the Lower Dniester meadow on the Kopanca territory. At present, this drainage system provides the permanent groundwater level deeper than 2 m from the terrestrial surface.
The irrigated and investigated alluvial soils from the Lower Dniester meadow are characterized by the following types: *Ahp1 (0-20 cm)→ Ahp2 (20-38 cm)→ ABh (38-57 cm)→ Bhg (57-80 cm)→ Abhg (80-95 cm)→ Bbhgk (95-115 cm)→ Gk1 (115-135 cm)→ G2 (135-160 cm)→ G3 (160-200 cm)* (Figure 2).

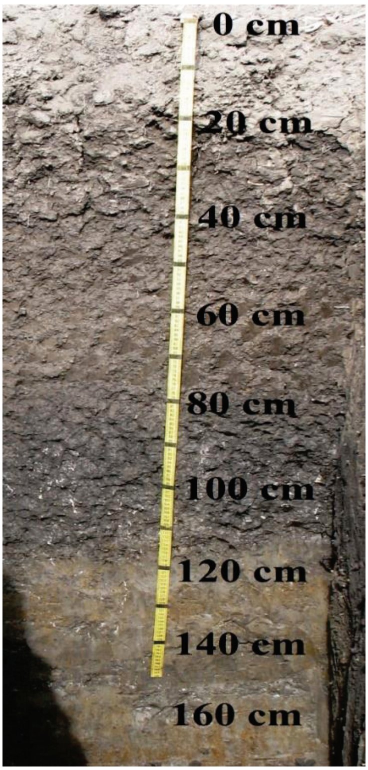

Figure 2. Alluvial irrigated soil of Lower Dniester meadow

RESULTS AND DISCUSSIONS

Alluvisoils of Lower Dnieper meadow
Alluvial sod soil of the lower reaches of the Dnieper river, which is used for growing vegetable crops under conditions of drip irrigation, is characterized by a high degree of cultivation in the 0-20 cm. This layer contains more than 4 percent of humus (Figure 3), which is a high index for such soils and is characterized by an increased content of mineral nitrogen, very high content - mobile phosphorus and moderate - exchangeable potassium (according to Chirikov method).
The arable horizon of a given soil is no longer just a layer of soil that is being processed. In fact, this is a new genetic horizon with a specific structure, properties, ecological functions with respect to modes of perception of moisture, emission, metabolism and energy.

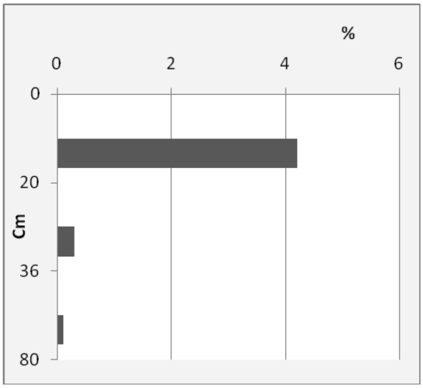

Figure 3. Content and profile distribution of humus in irrigated soil of the Dnieper river floodplain, %

The deeper horizons of this soil, subjected to much less influence of acculturation, have parameters typical for such soils formed on sands of alluvial origin. In the transitional horizon of this soil (20-36 cm) and deeper, the content of humus and mineral nitrogen is very low, phosphorus is medium and decreases to low, and potassium content is low.
The profile of alluvial meadow soil has significant differences in structure and agrochemical characteristics. Sandy loam with a thickness of about 10 cm has a very high humus content (Figure 4) and mineral nitrogen, increased content of phosphorus and medium content of potassium.

The humus horizon (10-25 cm) is characterized by a low content of humus, a very low level of availability with mineral nitrogen, medium - phosphorus and low - potassium.
In the first transition horizon (25-44 cm), there is practically no organic matter, very low content of mineral nitrogen, medium for phosphorus and low - potassium.

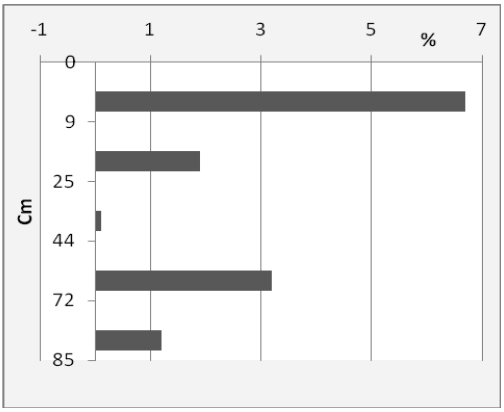

Figure 4. Content and profile distribution of humus in non-irrigated soil of the Dnieper river floodplain, %

The second transition horizon (44-72 cm) has an increased humus content, is characterized by a low level of mineral nitrogen, medium - for mobile phosphorus and potassium. It is actually a long-standing (ancient) humus horizon, buried beneath sandy alluvial sediments. Deeper in the profile, the content of humus, nitrogen, phosphorus and potassium decreases.
The studies did not reveal a statistically proven negative effect of irrigation on the humus state of soils and the content of nutrients in them. Such data indicate a significant reserve of nutrients in soils and the need to take measures to conserve organic matter.
A greater influence on the differentiation of the soil cover and its fertility is caused by the diversity of the geomorphologic - lithological characteristics of small areas of the floodplains of large rivers, which caused the differences in the agrochemical characteristics of alluvial soils under study.
The investigated soils distributed in the lower reaches of the Dnieper river quite clearly reflect the conditions of their formation: a shallow level of fresh surface water of 1-2 m, which ensures a constant moistening of the soil throughout the depth of the profile, short-term flooding, remoteness from the river bed.
Non-irrigated soil, more closely approximated to the bed of the river, is characterized by stratification of the profile and presence of the humus horizon buried by the alluvium sediments. Irrigated soil is located a little further (20 m) from the river bed. Its profile is more cultivated.
Of concern occurrence is the level of groundwater on the irrigated land - it is close to 1 m from the surface. This is less than the critical depth that threatens flooding, salinize-tion and alkalinization of irrigated lands and requires the use of artificial engineering drainage and a set of appropriate agro-amelio-rative and agro-technical measures.
The soil cover of the river floodplains, even relatively small areas, is complex and diverse in morphogenetic structure, composition and properties. Specificity and variegation of the soil cover of the floodplains of large rivers as Dnieper and Dniester necessitates a clear differentiation of the methods and technologies of using these lands, the normalization of anthropogenic loads on them.

Alluvisoils of Lower Dniester meadow

Regarding to the provenance of the alluvial irrigated soil profile by sedimentation of the alluvial deposits, the layered stratification of their profile in space and in depth is very variable. The profile of the studied soils is less differentiated in the upper horizons and is characterized by buried soils and gleyic horizons in the lower part. This is due to the fact that in the part under the terrace of the meadow, the overflows were rare, and after the construction of the dykes they were stopped.
Differentiation in more or less regular genetic horizons is only observed up to a depth of 80 cm. In the depth range of 80-95 cm there is a humid horizon Abhg, formed in another historical period. Under this horizon there is an extremely pronounced gleyic horizon with thin humic layers. So, the profile of the studied soil is composed of the buried gleyic soil, very humid, situated at the depth of 80-200 cm; and the contemporary soil with humiferous developed profile, poorly gleyic in the lower part, situated in the depth range of 0-80 cm.
The average pH values on the studied soils are basically analogous: 8.0-8.1 ± 0.3. The reaction

of the soil solution is slightly alkaline. The accuracy of the average pH indices is 1.6-2.1%. Parameters of this index are characterized by a small variation in space (V=3.2-4.3%).
The average humus content in the irrigated soil profile ranges from 2.98% ± 0.45% in the arable layer to 2.27% ± 0.49% in the underlying Bhg layer. In the buried soil the humus content ranges from 2.69% ± 0.31% in the Abhg horizon to 2.18% ± 0.32% in the Bbhgk horizon. The humus content in the gleyic horizons varies within the range of 1.01-1.31%, due to the existence of thin humic layers that practically imbibes these horizons with them (Table 1).

Table 1. Physic-chemical properties (average) of the irrigated alluvial soil of the Dniester river floodplain

Horizon and depth	pH (H_2O)	$CaCO_3$ %	Humus, %	C : N
Ahp1 (0-20 cm)	8.0	2.6	2.98	10.7
Ahp2 (20-38 cm)	8.0	3.2	2.71	10.3
ABh (38-58 cm)	8.1	3.6	2.51	9.8
Bhg (58-79 cm)	8.1	2.3	2.27	-
Abhg (79-95 cm)	8.1	1.4	2.69	-
Bbhgk (95-111 cm)	8.0	1.2	2.18	-

After the humus content in the arable layer the studied soils are submoderate to moderately humiferous, which is absolutely unjustified for soils with fine clayey texture (Figure 5).

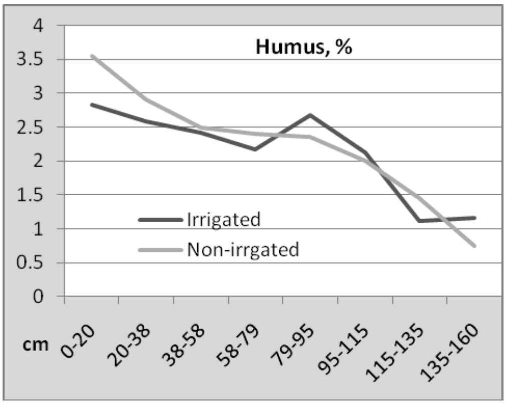

Figure 5. Humus in alluvisoils, irrigated and non-irrigated (Dniester meadow)

The mobile forms of P_2O_5 content is 9.7 ± 1.2 mg/100 g in the recent arable layer and 8.5 ± 1.3 mg/100 g in the ABh horizon.
According to the mobile phosphorus content, the investigated soil falls within the category of those with very high insurance of this element.
The content of mobile forms of K_2O in the studied soils ranges from 35.5 ± 1.8 mg/100 g of soil in the arable layer to 27 ± 1.4 mg/100 g of soil in the ABh horizon (Table 2).

Table 2. The content (average) of nutrients in irrigated alluvial soil of the Dniester River floodplain

Horizon and depth	Mobile forms, mg/100 g soil		
	P_2O_5	K_2O	$N\text{-}NO_3$
Ahp1 (0-20 cm)	9.67	35	0.287
Ahp2 (20-38 cm)	9.57	31	0.270
ABh (38-58 cm)	8.47	27	0.244

The content of mobile forms of K_2O in the studied soils ranges from 35.5 ± 1.8 mg/100 g of soil in the arable layer to 27 ± 1.4 mg/100 g of soil in the ABh horizon (Table 2).
According to the mobile potassium content the soil falls into the category of high insurance in this element (Cerbari, 2016).
The non-irrigated soils from the Lower Dniester meadow are characterized by a higher humus content in the 0-18 cm layer (3.15%). In depth, the humus content does not differ from that in irrigated soils.
The content of mobile forms in non-irrigated soils are: P_2O_5-11.00 mg/100 g of soil, K_2O - 50 mg/100 g, $N\text{-}NO_3$-0.560 mg/100 g.
On average, the mobile forms of nutrients represent an increase of 14% for phosphorus, 43% for potassium and 95% for nitrogen in the non-irrigated grasses soil layer compared to the irrigated arable layer.
The content of the mobile forms elements in the depth of the profiles does not differ.
Due to the clay texture, the low humus content, the unsatisfactory state of physical quality of the arable layer, these soils are a difficult object for irrigation use.

CONCLUSIONS

Irrigated soil of the flood plain of the Dnieper River is characterized by a high degree of cultivation of the 0-20 cm layer: high content of humus, nitrogen, phosphorus and potassium (according to the Standards of Ukraine).

In the deeper horizons of the soil, the content of nutrients and humus sharply decreases.

The upper horizon of the irrigated soil is also characterized by highly fertility indicators.

In the profile distribution of humus content in non-irrigated soil, two peaks are revealed: the sod and the buried humus horizon.

The content of nutrients from the sod deep into the profile of the non-irrigated soil is sharply reduced.

The level of occurrence of groundwater on irrigated land is of concern - it is close to 1 m from the surface.

The clay alluvial soils (irrigate and non-irrigated) from the lower Dniester River meadow are characterized by the following characteristics:

• layered profile with swamp clayey gleyic (fossil) burial soil at a depth of about 80 cm;

• contemporary soil with a thickness of 80 cm is characterized by homogeneous texture and developed humiferous profile, differentiated in genetic horizons;

• texture is clayey on the profile of the contemporary soil (up to about 80 cm deep) and fine clayey on the profile of the buried soil;

• good arable layer structure as a result of soil tillage, frost and thaw in the winter period;

• the underlying post-arable layer is characterized by unsatisfactory massive structure as a result of dehumification, destructuring and loss of compaction resistance;

• the high hygroscopicity values (9-10% in contemporary soil and 11-12% in buried soil) indicate large amount of wilting coefficient (large water reserves not accessible to plants);

• low profile carbonates (1-3%) and low alkaline reaction (pH 8.0-8.1) ensure normal growth of crop plants;

• the humic submoderate profile of the contemporary and buried soil;

• the high cationic exchange capacity of layers and horizons as a result of finely agglomerated and clayey texture ensures good adsorption of nutrients;

• the moderate content of the nitrogen content in the arable layer and small content in the underlying horizon is the result of the accelerated dehumification of these soils in arable and irrigation utilization rates;

• the high content of phosphorus (8.5-9.7 mg/100 g of soil) and mobile potassium in the soil totally assures the needs of crop plants in these elements.

The main measure of remediation of the quality of irrigated clay alluvisoils is the increase of the flow of organic matter into the arable layer and the restoration of the favorable structure.

ACKNOWLEDGEMENTS

This research work was carried out within the project „Agrogeochemical regularities of migration and accumulation of heavy metals in irrigated alluvial soils in the Dniester and Dnieper meadows", in accordance with the Protocol of the Moldovan - Ukrainian Commission for Scientific and Technological Cooperation signed on 13 November 2015 between the Academy of Sciences of Moldova and the State Agency for Science, Innovation and Informatization of Ukraine. Project nr. 17.80013.5107.09/Ua. Supreme Council Decision no. 292 (October 27, 2016).

REFERENCES

Cerbari V., Stegăreacu Gh., 2016. Quality assessment of irrigated fluvisol. Scientific paper. Series A. Agronomy, Vol. LIX, 33-38.

Baliuk S., Romashchenko M., Stashuk V., 2009. The scientific basis for the protection and management of irrigated lands Ukraine. 619 p. (Ukr.)

Baliuk S.A., Romashchenko M.I., Stashuk V.A., 2013. Complex measures against degradation on irrigated lands of Ukraine. 160 p. (Ukr.).

Revised World Soil Charter. Food and Agriculture Organization of the United Nations, 2015. Rome, Italy. http://www.fao.org/3/a-i4965e.pdf.

Soils quality, 2002. Determination of mobile compounds of phosphorus and potassium by modified Chirikov method: National Standard DSTU 4115-2002. 6 p. (ukr.)

Soil quality, 2004a. Sampling: National Standard DSTU 4287: 2004.10 p. (ukr.)

Soil quality, 2004b. Methods for determination of organic matter: National Standard DSTU 4289: 2004. 10 c. (ukr.)

Soil quality, 2007a. Determination of nitrate and ammonium nitrogen in modification of the NSC ISSAR named for O.N. Sokolovsky: National Standard DSTU 4729: 2007. 10 p. (ukr.)

Soil quality, 2007b. Preliminary processing of samples for physico-chemical analysis: National Standard DSTU ISO 11464: 2007 (ISO 11464: 2006, IDT)

(replacing DSTU ISO 11464: 2001) 14 p. (ukr.)
Ursu A., Overcenco A., Marcov I., 2012. Starea actuală a solurilor aluviale în luncile râurilor din sud-vestul Cîmpiei de Sud. Mediul ambiant, nr.1 (67). Chişinău: MM, 1-5.
Балюк С.А., Медведєв В.В., Мірошніченко М. М. та ін., 2012. Екологічний стан ґрунтів України. Український географічний журнал. № 2, 38-42.
Думих И., 2016. Морфогенетические особенности аллювиальных почв предкарпатья Украины. Știința agricolă, nr. 2. Chişinău: USM, 28-35.

CROP SCIENCES