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PECULIARITIES OF ALLUVIAL SOILS FORMATION FROM THE LOWER BOTNA RIVER MEADOW

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Abstract

The lower Botna meadow is located on the territory of Causeni district, 6 km south of the Botna river into the Dniester meadow, and characterized by the same absolute altitudes as the Dniester meadow. As a result of overflow waters, the Lower Botna meadow, a permanent swamp territory was formed with an area of about 2500 ha. Dams were built in the Dniester meadow in the 1950s, and the Botna meadow is no longer flooded by the floods of the Dniester. The swamp was drained, the groundwater level dropped to 1.5-2.5 m. The dry land has been used in agriculture for more than 60 years. At present, the soil covers of this territory, according to the WBR-14 classification, is formed by deep humic clayey alluvial soils with extremely deep humiferous profile. The humus content greater than 1.00% to a depth of 2 m and content of mobile phosphorus is 10-12 mg/100 g soil on the entire humifer profile. These endemic soils are described in Moldova for the first time and, due to the high content of humus (4.5-5.0%) and mobile phosphorus (12 mg/100 g), they are an extremely good object for the implementation in the organic farming.

Key words: *meadow, humus, Botna, mobile phosphorus, flood.*

INTRODUCTION

The genesis characteristics of the deeply humic alluvial soils were studied in the lower meadow of the Botna River. The Lower Botna meadow is located on the territory of Căușeni district, 6 km southwest of the Botna river overflowing the Dniester river, dreaming of the city of Tiraspol. The meadow is characterized by the same absolute altitudes as other meadows of the Dniester River. The absolute altitude of the surface of the lower Botna meadow varies: from 4 - 5 m at the outflow of the Botna river in the Dniester river on the territory of the meadow facing the village of Chircăiești; from 5-6 m - on the territory facing the village of Cârnățeni (16 km above the overflow site) and 6-7 m near the Căușeni (19-20 km above the overflow of the Botna in the Dniester river).

From the right side of the Botna river meadow, at its overflow in the Dniester river near the Chițcani commune, a horn-shaped hill advanced to the Dniester riverbed, which led to the major narrowing of the Dniester river meadow and the partial redirection of the annual floods to 18-20 km above the Botna river meadow. As a result of the annual floods that have been repeated regularly for millennia, a permanent swamp territory with an area of about 1800-2000 ha has formed the Lower Botna meadow (Figure 1).

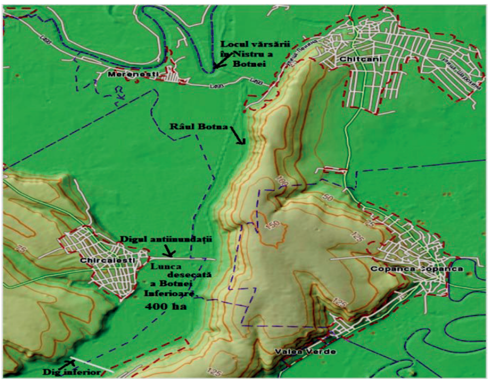

Figure 1. Lower Botna dried meadow on the territory of Chircăiești village, Căușeni district, R. Moldova

Dams were built in the Dniester river meadow in the 1950s, and the Lower Botna meadow was not flooded. In the 1950-1960 period, the natural swamp formed over the many years in the Lower Botna meadow was drained. The groundwater level in this territory has dropped to 1.5-2.5 m. The dry land 60 years ago was used in irrigated agriculture. Currently, the soil cover of this territory, according to the WBR-14 classification, consists of deeply humic alluvial soils (2.4-2.5% humus) with a carbon content in the layer 0-50 cm higher than 1.4%. These soils are post-marshy loamy, with extremely deep humus profile to a depth of 1.7-2.0 m (humus content greater than 1.00% and mobile phosphorus content 10-12 mg/100 g on the entire humiferous soil profile). These endemic soils in Moldova are described for the first time and, due to the high content of humus (4.5%-5.0%) and mobile phosphorus in the arable layer, it is an extremely favorable object for the implementation in the organic agriculture.

MATERIALS AND METHODS

In the research process of the ground cover of the Lower Botna meadow, the methods approved in the Republic of Moldova were used to carry out pedological research in the field, laboratory and office. In the field were placed 2 soil profiles (7 and 8) with the depth up to the groundwater (Figure 2).

Figure 2. Location of the profiles 7 and 8 in the Lower Botna meadow on the territory of Chircăiești commune, Căușeni district, R. Moldova

The groundwater level in the recently dried meadow varies from a depth of 2.5 m in the middle of the meadow (profile 7) to 1.5 m - in the meadow next to the riverbed (profile 8).
The bulk density in the field was determined by the cylinder method and the resistance to soil penetration with the Golubeva penetrometer. For laboratory analysis, samples were taken from each genetic horizon of the soil profiles. The analyzes were performed according to the standardized methods in use.

RESULTS AND DISCUSSIONS

The researched soil profiles 7 was located in the middle of the meadow, and profile 8 - located near the Botna riverbed on the agricultural lands of Chircăiești village. The identification of soil taxonomic units and value classes for soil classification indicators at lower level was carried out on the basis of the Soil Classification of the Republic of Moldova (Cerbari, 2001; Крупеников, Подымов, 1987), Russian Classification System (Егоров, Фридланд, 1977), World Reference Base for Soil Resources WRB (2014); Methodology for elaborating pedological studies, Part III. Ecopedological indicators (Florea et al., 1987).
The soil profiles 7 and 8 is characterized by clayey granulometry (particle-size distribution) and analogous morphological indices, but the thickness of their genetic horizons differs due to the different depth of the groundwater level (Figures 3 and 4).

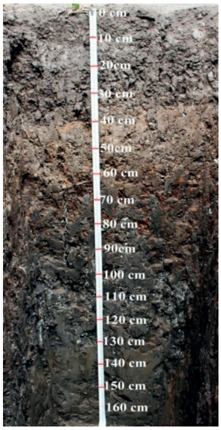

Figure 3. Profile 7. Deep humic alluvial soil after dried swamp (central meadow)

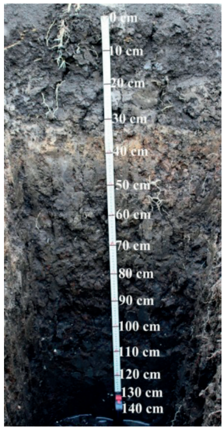

Figure 4. Profile 8. Deep humic alluvial soil after dried swamp (meadow near the river)

The researched soils has a profile type: *Ahp* - humiferous horizon, humus content 4.2-4.7%; *ABhr* - humiferous submoderate horizon with accumulations of iron oxides in capillary water; *Bhyz* - humic horizon with accumulations of the gypsum and soluble salts in the water of the

capillary fringe; *BGh* - humic gleyic horizon; *G* - mineral gleyic horizon deeper than 170 cm.
The humus of the humiferous horizons of the studied soil is gray-black. All the genetic horizons described have gone through the organic-gleyic phase of pedogenesis at different times. Permanent annual deposition of solid material in turbid stagnant water, *in situ* alteration of sedimentary deposits, as a result of gleyzation and enrichment of sediments with organic material in swamp conditions led to the formation of deep humic clayey soils with extremely deep humiferous profile (Figures 3 and 4).

As a result of arable land use after drying, it has been found that they have a high long-term fertility. However, the irrational exploitation of the soils in the last decades after the agrarian reform (the sudden replacement of the conventional tillage technology with the basic surface tillage according to the Mini-till technology) led to the strong compaction of the recently uncultivated soil section of the process of dehumidification and destructuring of this layer. The physical and chemical properties of the researched soils are presented in Table 1.

Table 1. Physical and chemical properties of humic alluvial soils in the Lower Botna meadow

Depth, cm	Soil particle content, %; diameter, mm		AH*	D*	BD*	RP*	Humus, %	$CaCO_3$, %	pH
	< 0.001	< 0.01							
Profile 7. Dried post-marsh humic alluvial soil with extremely deep humiferous profil, fine clayey, weakly carbonated, gleyzation in profile and deep gleyic, arable (central part of the meadow)									
Ahp1 0-20	48.7	86.9	6.0	2.57	1.29	18	4.71	1.4	7.2
Ahp2 20-40	49.4	85.8	5.9	2.62	1.49	24	3.77	3.3	7.2
ABhr 40-90	52.5	90.2	6.1	2.65	1.49	24	2.69	4.1	7.1
Bhyz 90-130	62.6	90.1	6.8	2.67	1.51	25	2.16	2.5	7.1
BGh 130-170	63.6	90.4	5.8	2.66	-	25	1.73	1.9	7.1
G 170-250	49.2	80.0	4.8	2.68	-	-	0.83	2.2	7.4
> 250 cm	Groundwater appeared at a depth of 260 cm, with a stabilized level at a depth of 250 cm from the earth's surface								
Profile 8. Dried post-marshy humic alluvial soil with extremely deep humiferous profile, fine clayey, weakly carbonated, gleyzation on the profile and deep gleyic, arable (meadow nearby the river)									
Ahp1 0-20	47.5	85.3	5.4	2.60	1.27	15	4.26	2.9	7.4
Ahp2 20-35	48.1	83.9	5.4	2.63	1.41	25	4.17	3.2	7.3
ABhr 35-60	45.5	80.8	6.3	2.65	1.42	23	2.18	6.1	7.4
Bhyz 60-90	52.9	84.9	5.9	2.66	1.44	22	2.25	5.2	7.4
BGh 90-135	61.4	85.2	6.2	2.68	-	20	3.17	2.5	7.5
BGh 135-150	60.3	86.8	6.8	2.69	-	19	2.87	2.2	7.6
> 150 cm	Groundwater appeared at a depth of 160 cm, with a stabilized level at a depth of 150 cm from the earth's surface								
*AH - hygroscopic water, %; D - density of the solid part, g/cm^3; BD - bulk density, g/cm^3; RP - penetration resistance, kgf.									

Due to the clayey granulometry the compaction of the soil in general and especially in drying condition is strong. In the last 30 years, the organic fertilizers have not been applied into the soil. The flow of fresh organic matter in this layer has clearly decreased which has led to a decrease in soil resistance to compaction.
In the 2000 year, the soil on the field where profile 7 was placed was worked with the subsoil to the depth of the former arable layer 35-40 cm and on the field where profile 8 was placed was ploughed to a depth of 20 cm. The 20-35 cm section of soil that has not been ploughed for many years has been strongly compacted. The roots of agricultural plants hardly penetrate into this compacted layer or pass only through cracks.
Both fields in the 2020 - an extremely drought year were sown with corn. The corn harvest was formed only on the field by the river from the capillary fringe water account, located in the soil at the depth of 50-150 cm. The toxic salts content in this stratum of 50-100 cm, in which the roots of corn have penetrated, constitutes 0.054-0.088%, that corresponds to the salinization degree of soil: from salinized to weakly salinized.

The information on the salt content, reaction and ionic composition of the aqueous extract of the alluvial soils in the lower Botna meadow based on the data obtained for soil profile 7 (deep humic alluvisoil in the central part of the meadow) and soil profile 8 (deep humic alluvisoil located near the riverbed) is presents in Tables 2-5.

Table 2. Salt content, reaction and ionic composition of the aqueous extract in the alluvial soil in the lower Botna meadow (profile 7)

Depth, cm	Dry residue, %	pH	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	$\frac{Na^+}{Ca^{2+}+Mg^{2+}}$
			mg/100 g soil %						
0-20	0.106	7.75	0.48 0.029	0.07 0.002	1.10 0.053	0.77 0.015	0.81 0.006	0.07 0.002	0.04
20-30	0.081	7.45	0.52 0.032	0.10 0.004	0.67 0.032	0.63 0.013	0.53 0.006	0.13 0.003	0.11
30-90	0.517	7.55	0.35 0.021	0.23 0.008	6.62 0.318	4.71 0.094	1.53 0.018	0.96 0.022	0.15
90-130	0.903	7.35	0.25 0.015	1.70 0.060	10.69 0.513	6.25 0.125	2.47 0.030	3.92 0.090	0.45
130-170	0.713	7.27	0.20 0.012	2.50 0.088	7.40 0.355	4.94 0.099	1.68 0.020	3.48 0.080	0.52
230-250	0.199	7.52	0.34 0.021	0.53 0.019	2.05 0.098	1.04 0.021	1.01 0.012	0.87 0.020	0.42

Table 3. Content of soluble salts (me/100 g) in the alluvial soil from the lower Botna meadow (profile 7)

Depth, cm	$Ca(HCO_3)_2$	$CaSO_4$	Na_2SO_4	$MgSO_4$	$MgCl_2$	NaCl	Toxic salts, %	
							total	from the residue
0-20	0.5	0.3	0.1	0.7	0.1	-	0.052	49
20-30	0.5	0.1	0.1	0.4	0.1	-	0.040	49
30-90	0.4	4.4	1.0	1.3	0.2	-	0.157	30
90-130	0.3	6.0	3.9	0.8	1.7	-	0.405	45
130-170	0.2	4.7	2.7	-	1.7	0.8	0.317	44
230-250	0.3	0.7	0.9	0.5	0.5	-	0.116	58

Table 4. Salt content, reaction and ionic composition of the aqueous extract in the alluvial soil in the lower Botna meadow (profile 8)

Depth, cm	Dry residue, %	pH	HCO_3^-	Cl^-	SO_4^{2+}	Ca^{2+}	Mg^{2+}	Na^+	$\frac{Na^+}{Ca^{2+}+Mg^{2+}}$
			me/100 g soil %						
0-20	0.141	7.68	0.38 0.023	0.07 0.002	1.66 0.080	0.84 0.017	1.15 0.014	0.12 0.003	0.06
20-35	0.102	7.77	0.45 0.027	0.14 0.005	1.00 0.048	0.74 0.015	0.67 0.008	0.18 0.004	0.13
35-60	0.101	7.90	0.55 0.034	0.21 0.007	0.79 0.038	0.70 0.014	0.35 0.004	0.50 0.012	0.48
60-90	0.163	7.80	0.55 0.034	0.68 0.024	1.22 0.059	1.02 0.020	0.47 0.006	0.96 0.022	0.64
90-135	1.142	7.40	0.30 0.018	0.48 0.017	14.85 0.713	10.37 0.207	2.65 0.032	2.61 0.060	0.20
135-160	0.869	7.32	0.24 0.015	0.89 0.030	10.84 0.520	6.17 0.123	2.10 0.025	3.70 0.085	0.45

Table 5. Content of soluble salts (me/100 g) in the alluvial soil from the lower Botna meadow (profile 8)

Depth, cm	$Ca(HCO_3)_2$	$CaSO_4$	Na_2SO_4	$MgSO_4$	$MgCl_2$	NaCl	Toxic salts, %	
							total	from the residue
0-20	0.4	0.5	1.1	1.1	0.1	-	0.076	54
20-35	0.4	0.3	0.2	0.5	0.1	-	0.052	51
35-60	0.6	0.2	0.5	0.1	0.2	-	0.054	53
60-90	0.6	0.5	0.8	-	0.5	0.2	0.088	54
90-135	0.3	10.1	2.6	2.3	0.5	-	0.335	29
135-160	0.2	5.9	3.7	1.2	0.9	-	0.351	40

According to the data obtained for profile 7, regarding the content of toxic salts, the deeply humic alluvial soil is not salinized in the first 100 cm, but is moderately salinized in the depth of 100-200 cm. The soil salinization type is sulphatic. Gypsum ($CaSO_4$) predominates in the composition of soluble salts, that is important in terms of the protection of alluvisoils from solonization. The content of toxic salts varies in the second meter of the profile within the limits of 0.335-0.351%. The soil cover of the Lower Botna meadow has historically formed under hydromorphic conditions under the influence of both surface runoff and groundwater after the wetland has dried up. Tables 6 and 7 presents data on the total mineralization, chemical composition and toxic salts content of the surface waters Botna and Dniester rivers.

Table 6. Chemical composition of surface water of the Botna and Dniester rivers and groundwater in the central part of the meadow (profile 7) and in the meadow near the river (profile 8)

Water source	Minera-lization, mg/l	pH	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	Sum	SAR	PMg, %
			me/l mg/l									
River Dniester	432	7.17	- -	5.8 354	1.25 44	0.42 20	3.62 72	2.98 60	0.87 20	14.94 570	0.5	4.5
River Botna	3190	8.76	1.22 37	7.06 431	10.94 383	28.00 1344	2.70 54	8.52 102	34.78 800	93.28 3151	14.7	76
Profile 7	3784	7.03	-	20.50 1250	12.42 435	26.37 1266	36.00 720	12.86 154	10.43 240	118.58 4065	2.1	26
Profile 8	4260	7.18	-	12.54 765	13.11 459	37.50 1800	30.42 608	11.64 140	21.09 485	126.63 4257	4.6	28

Table 7. Content of soluble salts in surface waters (Dniester) and groundwater, me/l

Water source	$Ca(HCO_3)_2$	$CaSO_4$	$Mg(HCO_3)_2$	$MgSO_4$	$MgCl_2$	Na_2CO_3	Na_2SO_4	NaCl	Sum	Toxic salts, % of total
River Dniester	3.62	-	2.18	-	0.80	-	0.42	0.45	7.47	51.5
River Botna	2.70	-	3.14	-	5.38	1.22	28.00	5.56	43.3	89.6
Profile 7	20.50	15.50	-	0.44	12.42	-	10.43	-	59.29	35.9
Profile 8	12.54	17.88	-	-	11.64	-	19.62	1.47	63.15	47.7

According to the degree of mineralization and chemical composition the water from the Dniester River is very good and can be used without restrictions to irrigate the soils of the Lower Botna meadow. Botna river water, according to SAR and PMg values, does not meet the quality requirements for irrigation water (Tables 6 and 7). At present, the territory carbonated and are characterized by favorable pH values in the range of 7.2-7.4.

of the Lower Botna meadow is used for arable land and is characterized by a favorable unstable groundwater regime. In the event of irrational soil and water management, the hydrological regime may become unfavorable (that happens as a result of incorrect irrigation).

The arable post-marsh deep humic aluvial soils from the Lower Botna meadow are poorly

An extremely important index of these soils is the very high content of mobile phosphorus on the entire humic profile, up to a depth of about 2 m (>10 mg/100 g soil). Such soils, with historical analogous solification conditions (gradual synergistic accumulation over thousands years of fine alluvial-proluvial deposits mixed with organic ones, rich in mobile phosphorus, formed in swamp pedogenesis codes) are very rare. Phosphorus is a strategic element that makes possible the use alluvial soils from the Lower Botna meadow in the organic farming.

CONCLUSIONS

At present, the soil cover of the Lower Botna meadow is used in non-irrigated agriculture. In the post-sovietic period, about 30 years ago, after its dried in the 1960s, the territory with these endemic soils was irrigated. After the land reform of 1990s the irrigation system was completely damaged and soils are no longer irrigated.

The process of pedogenesis in synergistic conditions of swamp and periodic flooding of the Dniester meadow over a long period of time, followed by drained and use as arable land for about 60 years, led to the formation of the deep humic alluvial soils (humus in upper layer is 4.0-5.0%) with extremely humiferous profile to a depth of 1.7-2.0 m and very rich in mobile phosphorus.

The researched soils are characterized by a high level of natural fertility. Rich in humus and mobile phosphorus it is recommended to restore the unfavorable physical properties of the arable soil layer by increasing the flow of qualitative organic matter in this layer.

Reducing the negative consequences of climate change that directly affect the degradation of the post-arable layer 0-30 or 0-35 cm is possible only by moving to green farming that provides for the systemic use of green mass of leguminous ameliorative plants (autumn and spring vetch or peas) as an organic fertilizer coupled with the gradual periodic implementation of the mini-till system.

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