HUMUS CONDITION OF CHERNOZEM SOILS IN SOUTHWEST OF UKRAINE

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Results of research for status of humus of chernozem soils in southwestern Ukraine are summarized. Geographic and genetic features of humus status of soils on the territory under study are identified. Chernozem soils under study are found to reveal a tendency, in dehumification processes, to retain their parameters being typical for soils of the chernozem-type soil-formation. Features of humus formation processes under impact of natural and man-caused factors were studied as well.

Keywords: chernozems soils, humus condition, Ukraine

AIMS

One of the global aspect of soils' degradation is their dehumification, since the contents of humus is an integral index of soils' fertility that displays an ecological and genetical status thereof. Of a special alert attention is dehumification of chernozem soils whose parameters are recognized as reference values of the superior soils quality worldwide. Making up over a half of agricultural land of Ukraine, chernozem soils hold a leading place in the natural and economic potential of the country. Agricultural exploitation of chernozems brings to depression of humus neoformation-process due to reduced income of fresh organic matter and to increased rate of its mineralization. Period of intensive dehumification takes place within first 30-60 years of chernozems' agricultural development being then followed by a period of stabilization and, possibly, accumulation of organic matter in the soil (*Laktionov, N.I. et al., 1999*). Duration of such periods differs across natural zones *(Kononova, M.M., 1963)*. There are also available some data on different rates of dehumification processes throughout the steppe zone that eventually brings to up-leveling the soils' differentiation over this territory in terms of the humus contents *(Yarmak, V. et al, 2007)*.

Quantitative changes of humus contents are known to be accompanied by changes of quality indices being of controversial character relatively to chernozems. Thus, research by V.V. Degtyaryov testifies to reduction of humine acids' contents in ordinary chernozems from the outset of agricultural use (taking a 27-year arable site as an example) as compared with virgin land; whereas further exploitation of 65-year and 120-year old plots of arable land evidences of accumulation thereof. In this case, duration of agricultural land-use doesn't affect the relative contents of fulvic acids *(Degtyaryov, V.V., 2011.)*. In studies for typical chernozems, M.V. Kapshtyk points out to increase of relative contents of humine acids alongside reduction in quantity of insoluble residue within the arable land, contrast to that with 16-year old wild brise plot *(Kapshtyk, M.V., 2009*). According to A.D. Balayev, humus contents of the southern chernozem of the 45-year old brise plot is characterized by elevated relative amount of humine and fulvic acids, contrast to that in the arable land, alongside lesser contents of the insoluble residue. However, humus contents of the typical chernozem was slightly different *(Balayev, A.D., 1986)*.

Monitoring of humus contents in soils over the territory under study has revealed its reduction within last decades to 0.35% on the average (ranging between 0.1 to 0.7% in certain areas) *(Golubchenko, V.F. et al., 2010)*. The comparative analysis with usage of data by A.I. Nabokikh (*Nabokikh, A.I., 1915*) shows that within recent 100 years, the superficial horizon of southern chernozems (within the range of the territory under study) has consecutively lost its humus contents by 25-40% (*Yarmak, V. et al., 2007)*. In this concern, an actually important task is identification of present-day zonal and local features of humus- quality indices under dehumification conditions that influence physical properties of chernozems and their ability to withstand the negative ecological factors.

METHODS

In terms of physico-geographic division of Ukraine, the territory of this present research is situated within limits of the Steppe zone. The climate of this territory is moderately continental, characteristic with insufficient humidity contents, short mild winter and lengthy hot summer. Annual sum of active temperatures makes up 2800°-3300°C, whereby the frost- free period lasts over 170-190 days. Amount of

precipitation all over the Steppe zone decreases from ~475 mm to ~350 mm from North to South, while depth of the soil wetting and thickness of soil profile decrease respectively. Therefore experts divide the Steppe land in two subzones: the North Steppe with its ordinary chernozems and the Mid-Steppe with southern chernozems. The Steppe-zone soils naturally originated on loessial bottom-bed under field grass and weed vegetation which is represented by tipchak and feather-weedle associations and which is, the further to the South the more becoming blinded due to elevation of aridity in the dry steppe climate. At present day, almost all land sites are ploughed up and used mostly for cultivating grain and forage crops. Irrigation techniques, along with other agro technical methods, are used to increase fertility of chernozems over drought-suffering territories.

Five key plot sites were arranged for the research experiment, assuming for places of their location capable of reflecting every typical geographic and genetic peculiarity of chernozems' humus-status. Features of soil formation were investigated on several key plot sites of the northern subzone (ordinary chernozems) and the southern subzone (southern chernozems, for example). Key plot sites located in Trans-Dniester area reflect facial features of soil-formation processes (for example, with ordinary micellar and carbonate chernozems). Local features of humus status were also investigated on territories brought out of irrigation in recent decades (southern chernozems) and in the area of Lower Danube super-floodplain terraces (with southern carbonate chernozems).

Research object: humus status of soils and their buffer abilities. Granulometric structure has been identified by aid of N.A. Kachinsky's techniques and interpreted via modification by S.I. Dolgov and A.I. Lichmanova *(Vadyudina, A.F.et al., 1986)*. The humus contents was identified by method of V.I. Tyurin in modification of B.A. Nikitin *(Arinushkina, E.V., 1970*), whereas humus group structure was assessed by methodology of M.M. Kononova and N.P. Belchikova *(Kononova, M.M., 1963., Kononova, M.M. et al, 1961*). Optical density was evaluated on an extract from humine acids obntained during humus contents identification *(Plotnikova, T.A.et al., 1967)*.

Rates of profile humus-accumulation coefficient (PHAC) and relative humus- accumulation coefficient (RHAC) were calculated per index of humus contents in the profile and per amount of physical clay, respectively *(Polupan, N.I. et al., 2005)*.

RESULTS

Granulometric structure of soils. Characterizing the soils under study according to the contents of physical clay, authors noted the following features (see the Table below). Ordinary chernozems are represented by heavy silty loam with coarse dust filling. Dominating fractions of ordinary chernozems all over the profile are silt (with particles' size ~0.001 mm) and coarse dust (of 0.05-0.01 mm particles' size). Southern chernozems deprived of irrigation include relatively high contents of physical clay (up to 46-48%), which fact characterizes them as heavy loam soils.

Southern chernozems and southern carbonate chernozems are represented by medium loam fraction (35-42% physical clay). Unlike ordinary chernozems, southern chernozems are characterized by prevalence of coarse dust fraction all over the profile, versus contents of silt fraction. Exception hereof are southern carbonate chernozems of super-floodplain terrace of the Danube river, whereby the next prevailing fraction is fine sand (of 0.25-0.05 mm particles' size).

The most dense contents of coarse and average sand fraction (1-0.25 mm particles' size) is observed in the bulk of ordinary micellar carbonate chernozems that can affect physical properties of agro soil, promoting soil-siltation and formation of soil-crust after precipitation.

Contents of fine and medium dust (0.005-0.001 mm and 0.01-0.005 mm, respectively) in all soils under study makes up about 10%, causing siltification and deflation processes. Sum of physical clay fractions tends to increase down the profile in all soils under study, while prevalence of videlicet oozy fraction and its uniform redistribution, in the course of soil formation all over the profile, characterizes the chernozems of the territory under study with high absorbing ability.

The contents of humus in soil and its distribution across the profile. In the arable layer, the ordinary chernozems under study contain 3.6-3.8% and southern chernozems – 2.4-2.6% humus. In southern carbonate chernozems being relatively light per granulometric structure, quantity of humus makes up ~2.16%. It should be noted that today, there is no strict differentiation between chernozems of northern and southern territories of the steppe zone (in terms of humus-contents percentage manifested by A.I. Nabokikh early in the XX century (6.0-6.5% and 3.4-4.2%, respectively), which shows the present-day neglectable up-leveling of the humus-zonality importance (*Yarmak, V. et al., 2007)*. At the same time, geographical

regularity of humus distribution, i.e., reduction of the humus contents and thickness of the humus horizon from the North to the South, is still true.

Scale of humus accumulation can be estimated per total stock of humus that reflects the general contents of organic substances in soil. Chernozems under study are characterized by low amount of humus stock in a layer: 0-20 cm. Concerning ordinary chernozems, amounts of humus stock fluctuate within 85.6-89.4 ton/hectare, while making up about 68 t/hectare for southern chernozems. Poor stocks of organic substances (in a 0-20 cm layer) are typical for southern chernozems deprived of irrigation (making up about 60 t/hectare). The least value of this index is observed with southern carbonate chernozems of the Danube super-floodplain terrace (~50.4 t/hectare) that can be explained by low contents of humus in these comparatively light soils.

The soils under study are characterized by cumulative type of humus distribution in a soil profile, which is peculiar for maximum accumulation of organic matter from the surface, with gradual reduction of its contents with depth. Thickness of the humus- containing profile (H + Hp + Phk) of chernozems under study, expressed as a degree of soil- formation process- development, is considered to be of medium value (65-85 cm). Rather notable thickness of the humus-containing portion of a profile in ordinary micellar and carbonate chernozems, was noted in comparison with that of modal soils (85 cm vs 70 cm, respectively). Thickness of their humus-cumulative horizon (H) makes up about 40 cm. Concerning southern chernozems under study, depth of the humus-containing portion is associated with their geographical situation and their granulometric structure. Thus, in mid-loamy southern chernozems and southern carbonate chernozems around the Danube super-floodplain terrace, depth of the profile humus-containing portion amounts to 72-75 cm, while thickness of their humus-cumulative horizon (H) makes up 34 cm. Heavy loamy southern chernozems deprived of irrigation possess about 67 cm thickness of the humus-containing profile. A more or less thick humus horizon (up to 44 cm) and a number of medium-humus "tongues" and “lips” in the bottom portion of the humus-containing profile are characteristic indexs of irrigated soils *(Poznyak, S.P., 1997)*.

General stock of humus in a profile is defined by a soil- formation- type, whereas that in profile-limits is determined by granulometric structure, wetting and profile-thickness. Dr. N.I. Polupan considers humus as a delicate index of soil-typological and ecological memory of the soil. He suggests an idea to consider a ratio of profile humus-contents and its physical clay contents as a diagnostic index of a soil-formation type and a subtype, correspondingly *(Polupan, N.I. et al., 2005)*.

Thus calculated coefficients of profile accumulation of humus (PHAC) reflect reduced intensity of a profile humus accumulation in North-South direction, which is supported by the PHAC-corresponding statistical data: from 0.051-0.052 to 0.041-0.043, respectively. It reflects factor of soil-formation and humus-accumulation zonality in a given region. Values of relative humus accumulation coefficients (RHAC), in their turn, reflect an elevation of the climatic aridity and, correspondingly, a decrease of humus accumulation in the southern portion of the steppe zone. From ordinary chernozems to southern ones, RHAC value decreases by 24% (from 0.73 to 0.53 respectively). It should be noted that in comparison with the reference values *(Polupan, N.I. et al., 2005)*, factual values of PHAC data for ordinary and southern off-irrigation chernozems, are somewhat belittled. Values of RHAC correspond to reference standards and reflect classification identity of the soils between moderately weak humus-cumulative ordinary chernozems and weakly- accumulated southern chernozems.

Qualitative structure of humus. Dynamics of humus accumulation processes in soil influences the qualitative structure of humus being estimated by the contents and a ratio of various groups of humine substances that differ in their properties, such as: humine acids, fulvic acids and an insoluble residue. Concerning the soils under study, the group structure of humus is characterized by relatively high amount of humine acids and rather low percentage of fulvic acids that is peculiar to soils of chernozem-type soil-formation *(Plotnikova, T.A., 1969)*.

A relative contents of humine acids in an arable layer of ordinary and southern chernozems, on the territory under study, is ranging within 26-40% out of the general carbon amount. The least contents of humine acids is registered in southern carbonate chernozems whose mid-loamy structure causes low absorbing ability alongside an effect of coagulation which is necessary for fixing up the newly formed humine substances.

A relation between humine acids contents (C_{hac}) and fulvic acids contents (C_{fac}) characterizes the humus type, thus reflecting specifics of humification processes in different soils. The ordinary chernozems under study are characterized by fulvatic & humatic type of humus in arable layer, at the C_{hac}:C_{fac} ratio within 1.76-1.84. In humus horizon, there is observed elevation of relative contents of humine acids and rise

of Chac:Cfac ratio up to 2.02-2.21 that evidences of humatic type of the humus-formation. In relation to southern chernozems, characteristic is a gradual reduction of relative and absolute contents of humine acids down the profile and, consecutively, decrease of C_{hac}:C_{fac} ratio across the depth. The humus-cumulative horizon of southern chernozems is characterized by humatic type- humus (at C_{hac}:C_{fac} ratio ~2.27). Concerning the free-from-irrigation southern chernozems studied, as well as southern carbonate chernozems of the Danube super-floodplain terrace, humus is fulvatic & humatic type with C_{hac}:C_{fac} ratio within 1.75-1.87, gradually decreasing down the profile.

Relative contents of the insoluble residue in ordinary and southern chernozems under study is of medium value (42-59%). It should be noted that insoluble residue contents is low in off-irrigation southern chernozems at the depth below 70 cm, and in ordinary chernozems below 110 cm.

Organic residues transform into humine substances most completely in ordinary chernozems, which fact is testified to by high degree of humification (31.0-38.5) within humus-containing portion of profile. Extent of southern chernozems humification is highest (36.2-40.0%) within 0-30 cm thick top layer of the soil, whereas with depth this index decreases, making up 22.0-26.3% on the average. Exception hereof are southern carbonate chernozems of the Danube super-floodplain terrace, characterized by a mediate degree of humification, which becomes weak below the depth of 24 cm (10.1-19.5%).

Optical density of humine acids. It has been determined by indices of humus status of soils *(Orlov, D.S., 1990)* that humine acids of chernozems under study possess high and abnormally high optical density which is associated with heavily condensed aromatic nuclei and low contents of lateral aliphatic radicals in their molecules. In ordinary micellar and carbonate chernozems and in southern carbonate chernozems, optical density coefficients possess high values, such as 0.177-0.195. Abnormally high optical density coefficients (0.223-0.275) of humine acids in ordinary and southern chernozems evidence of a dense compactness of aromatic nuclei in their molecules, and point out to rather favorable conditions at formation of compound forms of humine acids in these soils.

Structure and properties of humine acids normally undergo changes in the soil profile, that is noted by numerous authors *(Kononova, M.M., 1963, Plotnikova, T.A., 1969., Podvalnaya, H., 2003)*. In soils under study, lesser values of optical density coefficients are observed in arable layers, which fact can be a consequence of fresh organic residues' accumulation and presence of chemically rather "juvenile" humine acids *(Kononova, M.M., 1963)*. Availability of more or less "mature" humine acids is observed in the lower portion of the humus-cumulative horizon, which fact is testified to by elevation of optical density coefficients. In lower portion of the soil profile were noted low indices of humine acids' optical density, probably as a result of downstream of mobile humine acids (of a simplified structure) from upper horizons. This fact was also marked out by T.A. Ponomareva in her research for southern chernozems *(Plotnikova, T.A., 1969)* that, according to M.M. Kononova, is explainable by genetic affinity between humine acids and fulvic acids, alongside probability of existence of transitional forms therebetween *(Kononova, M.M., 1956)*.

It should be noted that with depth, the humus-cumulative horizon of ordinary modal chernozems is characterized by gradual decrease in optical density of its acids. Uniform distribution of these indices within a profile is caused by humus- formation conditions favorable for: genesis of highly structurized molecules of humine acids, upgrade of hydrophobic properties and deceleration of their mobility in upper layers.

For purpose of comparison between optical properties of humine acids, there has been computed a chromaticity- coefficient based on ratios of extinction- coefficients at 465 and 665 nm wavelengths (at a rate of E4:E6). This ratio doesn't depend on carbon concentration while reflecting a degree of the condensed aromatic nuclei' input to construction of humine acids' molecules *(Kononova, M.M., 1956, Kononova, M.M., 1972)*. Abnormal structurization of molecules is observed in arable layers of ordinary modal chernozems, southern modal chernozems and off-irrigation southern chernozems, whereby the E4:E6 ratio makes up 2.8-2.9. Lesser structurization of humine acids' molecules, due to reduced interactivity of condensed aromatic neclea and, correspondingly, increase of lateral aliphatic chains, in construction of humine acids' molecules, is noted in ordinary micellar and carbonate and southern carbonate chernozems, where the increase in E4:E6 ratio makes up to 3.0-3.2. On other words, the humus in these soils is represented by juvenile, less matured humine acids.

CONCLUSIONS

Due to deficiency of organic fertilizers within recent 10-20 years, the arable horizon of chernozem soils in the southwestern Ukraine has undergone a loss of humus contents up to 0.35% on the average (ranging from 0.1 to 0.7% in certain areas). Typical contents of humus in ordinary chernozems (in the southern strip of their geographical distribution area), versus that of southern chernozems, is ranging within

3.6-3.8% and 2.4-2.9%, respectively. Thus, during the last century, the upper (arable) horizons of southern chernozems have lost ~15-30% humus contents.

At apparent up-leveling of the humus status of both ordinary and southern chernozems, there still exists a zonal character of most of specific indices that characterize some processes of humus accumulation. Thus, with decrease of the profiled humus accumulation- intensity (from 0.051-0.052 to 0.041-0.043) and coefficient of relative humus-accumulation (from 0.73 to 0.53) in southward direction, general stock of the humus, alongside the thickness of humus-containing portion of the profile, also are reducing.

The group structure of humus and optical properties of humine acids are mainly specified by local conditions, such as granulometric structure of soils, distribution of carbonates in a profile, result of irrigation. The southern carbonate and mid-loamy chernozems are characterized not only with the least contents of humus, but also with weaker extent of organic matter humification and structurization of humine acids' molecules.

General features of soils studied are: cumulative distribution of humus over the profile; humatic and fulvato-humatic type of humus(Chac:Cfac ratio within 2.02-2.27 in ordinary chernozems and within 1.76-1.84 in southern chernozems); high degree of organic matter humification (~30%); a considerably condensed status of aromatic nuclei in humine acid molecules (at E4:E6 ratio about 2.8-3.2); in this concern, typical are medium and high buffer abilities in acid and alkaline intervals, depending on degree of humus concentration, carbonate indices and granulometric structure of soils.

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