

LESIA BUSLENKO*, RYSZARD DĘBICKI**, VOLODYMYR IVANTSIV*

THE INFLUENCE OF SOIL GRANULOMETRIC COMPOSITION
ON THE HOROLOGY OF EARTHWORMS

Abstract. The influence of granulometric composition of fractions from different soil horizons on the qualitative and quantitative composition of earthworms has been studied. The effect of granulometric fractions on the formation of humidity, temperature, gaseous regime, actual acidity as main abiotic factors in genesis of earthworms complexes in the soils of Western Volyn and Podillya has been described.

In the biocenosis of Western Volyn and Podillya, earthworms are represented by a system of complexes. Their genesis is conditioned by the granulometric composition of the soil profile. As a matter of fact, moisture, temperature, air, general physical, physicochemical and biochemical properties of soil horizons of biogeocenosis depend on the granulometric composition of soil horizons [2, 4, 5, 7, 9]. In spite of considerable importance of the granulometric composition of soils as a dominant edaphic factor of edaphotops in life activities of soils oligochaeta, there is no a complete understanding of the genesis mechanism of the earthworms' complex.

Currently, the granulometric composition of soil horizons attracts attention of numerous researchers as the main ecological regulator of biocenotic processes. In this regard, the main purpose of our research was to recognize the role of the granulometric composition of soils in the formation of complexes of earthworms in the following soils of Western Volyn and Podillya: light-grey forest,

*Asst. Prof. L. Buslenko, DSc.; Prof. V. Ivantsiv, DSc.; Department of Zoology, Volyn National University of Lesia Ukrainian, Potapova, 9, 43-025, Lutsk, Ukraine.

** Prof. R. Dębicki, DSc.; Department of Soil Science and Soil Protection, Faculty of Earth Sciences and Spatial Management, Maria Curie-Skłodowska University, Al. Kraśnicka 2cd, 20-718 Lublin, Poland.

light-grey forest gleyish, grey forest, wet grey forest, brownish-grey forest, dark-grey podzolic, typical low humus chernozem and typical wet chernosem.

MATERIALS AND METHODS

Material for this research has been collected and summarized on the basis of long-term (2001–2012) research of biogeocenosis in 162 representative sites of Western Volyn-Podillya. Selected and analyzed were 475 qualitative and quantitative *oligochaeta* samples of the *lumbricoides* family. To study the peculiarities of *lumbricidae* invasion of soil horizons with different granulometric composition, moisture, gaseous regime and actual acidity, we employed conventional pedozoological methods [1, 3, 6, 8]. Observation of life activities of earthworms was conducted in laboratory and field conditions. The animals were kept in microcosms and oligoterrariums.

RESULTS AND DISCUSSION

The analysis of the granulometric composition of fractions showed a significant influence of earthworms on their qualitative and quantitative composition. This was determined by the physical and physicochemical properties of primary and secondary minerals of the soil granulometric composition. Below, we consider the influence of different fractions of soil granulometric composition on the population of earthworm invasion.

Light-grey forest soils

The profile of light-grey forest soils is differentiated as to elluvial-iluvial type and represented by the following sequence of horizons: HE-Eh-I-IP-P. Granulometric composition is somewhat different from soddy-podzolic soils and is characterized by specific gravity. HE – 1.35 Mg m⁻³, Eh – 1.47 Mg m⁻³, Ih – 1.43 Mg m⁻³, IP – 1.48 Mg m⁻³, P – 1.54 Mg m⁻³. The share of sand in soil horizons decreases downwards (from 78.65 to 65.4 %), and of clay – increases (from 21.34 to 34.5%). The complex of soil oligochaeta in light-grey forest soils is represented by the lumbricidae species: *Aporrectodea caliginosa*, *A. rosea*, *Lumbricus rubellus*, *Octolasion lacteum*, *Dendrobaena octaedra*, *Dendrodrilus rubidus tenuis*. The dominating species were *Dendrodrilus rubidus tenuis*, *A. rosea*, subsp. – *Dendrobaena octaedra*. The other types were sporadically found in the samples. The number and biomass of lumbricidae were 80.2±2.7 sp. m⁻², 24±2.8 g m⁻², respectively.

Light-grey forest gleyish soils

These soils underlie the poorly drained water sheds and effluent terraced territories. The wildland variants of the soil profile have the humus-soddy horizon (Hd) 3–6 cm deep, humus-eluvial horizon (HE) – 20–30 cm deep (25–30 cm in acquired lands), grey, light-grey, fine grains and fine lumps. Eluvial (E) horizon is often without humus or unevenly and poorly humified (Eh).

Qualitative values of sand fractions are significantly different in the E horizon compared with HE, I_{pgl}. This is caused by intensive eluvial processes that result in minimal values of the silt fraction, and in some cases to their total absence and domination of fine silt (quartz). They are characterized by excessive actual acidity and low saturation with bases. As to the water regime, they can be referred to as semihydromorphic soils.

The soil oligochaeta complex of light-grey gleyish forest soils of Western areas of Ukraine is represented by seven lumbricidae species (*L. rubellus*, *A. rosea*, *A. caliginosa*, *O. lacteum*, *D. octaedra*, *D. rubidus tenuis*, *D. rubidus subrubicundus*). The dominating lumbricidae were *L. rubellus*, *A. rosea*, *A. caliginosa*. The number and biomass of the lumbricidae were 47.07±4.9 sp. m⁻², 12.37±3.4 g m⁻², respectively.

Grey forest soils

These soils underlie elevated slopes and were formed on loess-like loams. Grey forest soils differ by the soil profile structure when compared with light-grey forest soils. This soil type is characterized by the following profile horizons: HE-I-Pi. The depth of the humus-eluvial (HE) horizon reaches 28 cm, it has grey colour and a loose, silty-lumpy structure. The humus content is 2.1–2.6%. The illuvial (I) horizon is poorly humified (0.5–0.8%). The transitional horizon is represented by leached loess-like loam. Granulometric composition is characterized by somewhat lower content of sand and higher content of clay, which corresponds to average loam structure. In the HE and I horizons the silty fraction makes up 12.24 and 20.17% accordingly. These soils are insufficiently saturated with Ca²⁺ and Mg²⁺ cations, they are dusty and structureless.

The soil oligochaeta complex is well-developed, which is proven by its specious composition, number and biomass. It is represented by nine lumbricidae species – *A. caliginosa*, *L. rubellus*, *A. trapezoides*, *A. rosea*, *L. terrestris*, *O. lacteum*, *D. octaedra*, *D. rubidus tenuis*, *D. rubidus subrubicundus*. The dominating lumbricidae were *A. caliginosa*, *A. rosea*, *L. rubellus*. The lumbricidae number and biomass were 87.5±6.7 sp. m⁻² and 27.9±4.41 g m⁻², respectively.

Wet grey forest soils

These soils are spread on heavy (with respect to their granulometric composition) loess soils. High amounts of precipitation and low water infiltration of bedrock further regulate the overmoistening that leads to the development of gley processes. The characteristic feature of this soil is a well-developed powerful soil profile, deep leaching and high mobility of clay substances across the soil profile. The latter fill in the burrows, holes and fractures.

The soils are characterized by lower differentiation of soil profile in terms of the eluvial-illuvial type without a clear eluvial horizon. The structure of the soil profile is as follows: HE(gl)-Ihe(gl)-I(gl)-PI(gl).

The content of sand decreases downwards from 64 to 57%, and that of physical clay increases from 35 to 49%. From all physical clay fractions, the silty fraction has the highest mobility. Its content increases downwards from 11 to 33%. The total humus content in HE(gl) makes up 2.2–3.1%. In wet grey forest soils, the development of the soil oligochaete complex is not so obvious as in grey forest soils. It is determined by low water infiltration of bedrocks that leads to regular overmoistening and development of gley process across the whole soil profile. Moreover, there is high mobility of clayish substances across the soil profile.

The complex of soil oligochaeta is represented by nine lumbricidae species: *A. rosea*, *A. caliginosa*, *L. terrestris*, *O. lacteum*, *D. octaedra*, *A. trapezoides*, *L. rubellus*, *D. rubidus subrubicundus*, *D. rubidus tenuis*. Among them the dominating ones were *A. rosea rosea*, *A. caliginosa caliginosa*, *L. rubellus*. The number and biomass of lumbricidae were 53 ± 5.4 sp. m⁻² and 17 ± 1.9 g m⁻², respectively.

Brownish-grey forest soils

These soils were formed on light loess deposits under beach, as well as oak and beach forests. Good drainage of soils horizons and humid climate contribute to the development of burozemic features in grey forest soils. They have exhibited high leaching and low saturation with bases. The profile of brownish-grey forest soils is differentiated with regard to the elluvial-iluvial type. The soils of this type have lower specific gravity than grey forest soils. The combination of different edaphic factors furthers the formation of a well-developed complex of soil saprophages including lumbricidae. As to their granulometric composition, they differ from grey forest soils. In HE and I horizons, they have a lower content of clay and the silty fraction and somewhat higher content of average – and fine-size silt.

The complex of soil oligochaeta is well-developed, which is proven by their species composition, number and biomass. It is represented by nine lumbricidae

species: *A. rosea*, *A. caliginosa*, *L. rubellus*, *O. lacteum*, *A. trapezoides*, *L. terrestris*, *D. rubidus tenuis*, *D. octaedra*, *D. rubidus subrubicundus*. The dominating lumbricidae were *A. caliginosa*, *A. rosea*, *L. rubellus*. The number and biomass of lumbricidae were 71 ± 4.3 sp. m⁻² and 21 ± 3.5 g m⁻², respectively.

Dark-grey podzolic soils

In comparison with grey forest soils, they have less pronounced features of podzolic processes, but more accumulated organic substances. In wildland soils, the humus content reaches 4–8%. In its upper horizon, fulvic acids prevail ($C_{ha}:C_{fa}=0.7-0.9$) and in its middle part its composition approaches that of chernozems ($C_{ha}:C_{fa}=1.2-1.4$).

The soil profile of wildland soils in its upper part is represented by the soddy horizon (Hd), 2–5 cm deep. The depth of the humus-eluvial (HE) horizon reaches 36 cm, Hi – 30–35 cm. The soil has a low content of sand (48.14–32.71%). Its values are maximal in the HE horizon and they slowly decrease towards Pi (from 48.14 to 32.71%). Accordingly, the content of clay increased in soil horizons from 51.86 to 67.31%. This has reflected on the formation of the soil oligochaeta complex represented by eight lumbricidae species: *A. caliginosa*, *A. rosea*, *L. rubellus*, *Octodrilus transpadanus*, *O. lacteum*, *D. octaedra*, *D. rubidus tenuis*, *D. rubidus subrubicundus*. Among the lumbricidae, dominant are: *A. rosea rosea*, *O. transpadanus*, *L. rubellus*. Their number and biomass were 43.9 ± 6.5 sp. m⁻², 14.6 ± 3.4 g m⁻².

Wet dark-grey podzolic soils. These soils differ from wet grey forest soils through significant accumulation of organic substances and a deeper humified soil profile. The humus content in wildland soils reaches 8%. It is similar (with respect to its content and quality) to typical humus chernozems and at the same time preserves the characteristics of podzolic soils ($C_{ha}:C_{fa} < 1$). The humus horizon [He(gl)] is well eluviated with gleyish features. Its depth reaches up to 45 cm, dark-grey color with significant amount of rusty stains and bean-like formations. Transitional humus-illuvial [HI (gl)] and illuvial [I(gl)] horizons have features of seasonal gleying.

Granulometric composition of this soil type has a higher content of sand and a lower content of clay compared with wet grey soil. We should emphasize the high content of silty fraction in HI (gl), I (gl) horizons. However, in He(gl), Pi (gl), P(gl) it varied from 16 to 19%. The high content of the silty fraction in soil horizons and seasonal gley processes have a direct connection to the development of the soil oligochaete complex. It is represented by nine species: *A. caliginosa*, *A. rosea*, *O. transpadanus*, *L. rubellus*, *O. lacteum*, *D. octaedra*, *Dendrodrilus rubidus rubidus*, *A. longa*, *A. georgii*. The most widespread in the soils were: *A. caliginosa caliginosa*, *A. rosea rosea*, *Lumbricus rubellus*. The lumbricidae number and biomass were 56 ± 4.7 sp. m⁻² and 17.5 ± 2.9 g m⁻², respectively.

Podzolic chernozems

These soils underlie plain poorly drained water shed territories and always wedge between dark-grey podzolic soils and typical chernozems. The soil profile is characterized by low zoogenicity. In wildland soils, the humus content reaches 4–8%. Humin acids prevail in its content ($C_{ha}:C_{fa}=1.2-1.5$). The soil profile consists of poorly eluvial upper transitional humus (Hpi), lower transitional (Phi) horizon and bedrock (Pk).

The content of sand in soil horizons is slowly increasing downwards from 59.94 to 62.12%, and of physical clay decreases across the profile from 43.03 to 39.87%. The content of medium and fine silt in genetic horizons is high, and the content of silty fraction decreases from He to Pk horizons (25.51–24.81%). The high content of the silty fraction in He, Hpi, Phi horizons has significantly reflected on the formation of the soil oligochaete complex. Species composition is represented by: *A. caliginosa*, *D. octaedra*, *L. rubellus*, *A. rosea*, *L. terrestris*, *Drubidus subrubicundus*. The dominating species were: *A. caliginosa*, *D. octaedra*, *L. rubellus*. Their number and biomass were: 58 ± 6.1 sp. m⁻² and 17.6 g m⁻².

Typical low humus chernozems

These soils underlie the high loess terraces. They are characterized by features of a chernozem formation process: no redistribution of granulometric composition, deep carbonate deposits, humus accumulation. Formation of chernozem soils took place under the influence of herbal vegetation (soddy soil formation process), in case of deep groundwater occurrence (> 5 m) under conditions of normal moistening. The soils have a weal structure due to a dusty granulometric composition. The humus content varies between 2.2 and 3.9%.

The soil profile is represented by the following horizons: humus (He), humus transitional (Hkp), transitional (PHk), bedrock (Pk) – loess soil, brownish-yellowish or yellowish. Granulometric composition is characterized by a low content of sand in the soil horizons. Its value decreases from 47.48% in the humus horizon to 37.71% in Pk. Physical clay compared with podzolic chernozems has a high content of the silty fraction (33.9%) in the humus horizon that slowly decreases downwards to 26.47%. The high content of silty fraction in soil profile horizons has influenced the formation of the soil oligochaete complex.

Species composition of lumbricidae complex is represented by: *A. caliginosa caliginosa*, *O. transpadanus*, *A. rosea rosea*, *L. terrestris*, *O. lacteum*, *D. octaedra*. All species except *D. octaedra* belong to the soil's only morpho-ecological group. The dominating species were *A. caliginosa caliginosa* and *Octodrilus transpadanus*. The lumbricidae number and biomass were 37.5 ± 4.9 sp. m⁻² and 11.9 g m⁻², respectively.

Typical wet chernozems

These soils were formed on loess deposits. The genesis of typical wet chernozems took place in a humid climate with the seasonal excessive moistening. In wildland soils, the humus content varies from 5 to 9%. In the humus content, there is domination of humin acids over fulvic acids ($C_{ha}:C_{fa}=1.1-1.3$).

The soil profile is represented by the following horizons: humus (Hk) – dark-grey ($C_{ha}:C_{fa}=1.2-1.5$), dust, lumpy, hardpan, in lower part carbonated; humused-transitional (Hpk) – dark-grey with brownish hue/color, loose, with numerous vertical and horizontal holes made by soil oligochaeta, upper transitional (PHk) – poorly and unevenly humused due to bioturbation of burrowing animals; lower transitional (Phkgl) unevenly humused, with the signs of seasonal process of gleying in the form of rusty stains, light-dirty-brown color and a lumpy structure.

The content of physical sand and physical clay in the Hk horizon makes up 51:49%. However, there is a tendency for an increasing amount of physical sand within the soil profile. The content of the silty fraction compared with typical low-humused chernozems is lower and in the Hk horizon it makes up about 30%. In lower horizons it reaches 19%.

Formation of the soil oligochaete complex took place in steppe meadows in conditions of sporadic seasonal excessive moistening. The presence of the meadow stage in the genesis of typical wet chernozems conditioned the formation of carbonates. The lumbricidae complex is represented by *A. rosea*, *O. lacteum*, *O.transpadanus*, *D. octaedra*. The number and biomass of earthworms were 23.8 ± 2.9 sp. m^{-2} and 8.7 ± 0.8 g m^{-2} , respectively.

Among the soils of Western Volyn and Podillya, the particular group is represented by grey forest soils. It combines the features and properties of soddy-podzolic and chernozem soils. Granulometric composition of grey forest soils is characterized by a lower content of physical sand than in the soddy-podzolic soil (from 78 to 64%), higher content of physical clay – from 22 to 35%, silty fraction – from 10 to 33.9% (Fig. 1, 2), that determine the wide range of the lumbricidae complex development. The earthworm complex is best of all represented in grey forest soils (nine species), and their number reached 87.5 ± 6.7 sp. m^{-2} , biomass – 27.9 ± 4.4 g m^{-2} . Somewhat less the earthworms complex is developed in light-grey forest soils – 6 species, and their number made up 80 ± 2.3 sp. m^{-2} , biomass – 24 ± 2.5 g m^{-2} . In light-grey gleyish forest soils, the earthworm complex is represented by seven species, their number is 47.07 ± 4.9 sp. m^{-2} , biomass – 12.37 ± 2.4 g m^{-2} .

Dark-grey podzolic soils, compared to grey forest soils, have less expressed podzolic processes and a content of increased physical sand in the He horizon grows from 48 to 67%. Physical clay has increased from 33 to 52%, silty fraction

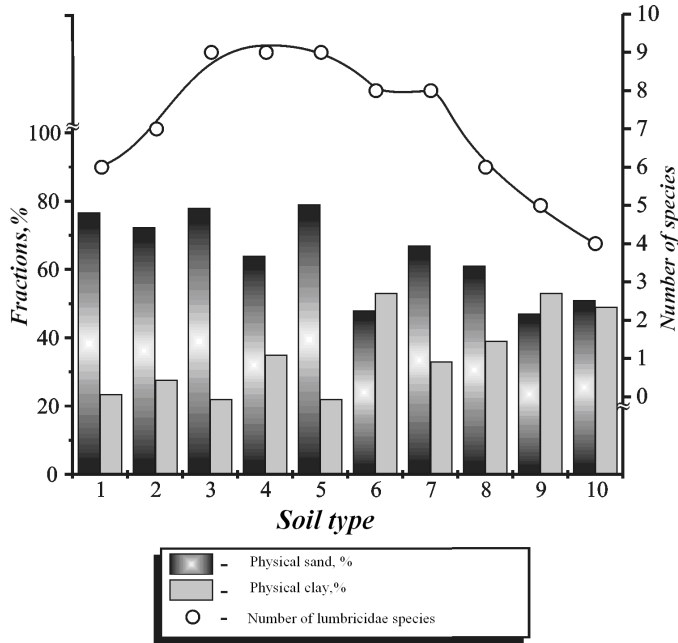


Fig. 1. Qualitative distribution of lumbricidae complexes depending on the fraction composition of soils of Western Volyn and Podillya: 1 – light-grey forest; 2 – light-grey forest gleyish soils; 3 – grey forest soils; 4 – wet grey forest soils; 5 – brownish-grey forest soils; 6 – dark-grey podzolic soils; 7 – dark-grey wet podzolic soils; 8 – podzolic chernozems; 9 – typical low-humused soils; 10 – typical wet chernozem.

– from 17 to 40%, humus content reaches up to 48%, saturation with bases – up to 93%. Actual acidity is pH 6.5–7.0. The reduction of porosity in the He horizon reaches 39.5% in dark-grey podzolic soils. The indicated differences of the soil influenced the number of lumbricidae (Fig. 2).

In terms of their physical, physico-chemical, biochemical properties, podzolic chernozems are similar to dark-grey podzolic soils. They are characterized by a high content of clay, silty fraction and a low content of physical sand and low total porosity (52%). The lumbricidae complexes are represented by six species, their number is 58 ± 6.1 sp. m^{-2} , biomass – 17.6 ± 2.5 g m^{-2} . In podzolic chernozems, the conditions are less favourable for the development of lumbricidae complexes. The primary reason for this is the granulometric composition. The high content of silty fraction causes the high absorbing capacity of water. The confirmation for this process is a high value of the withering point – 16.9%, i.e. the main role falls onto the absorption process and water evaporation.

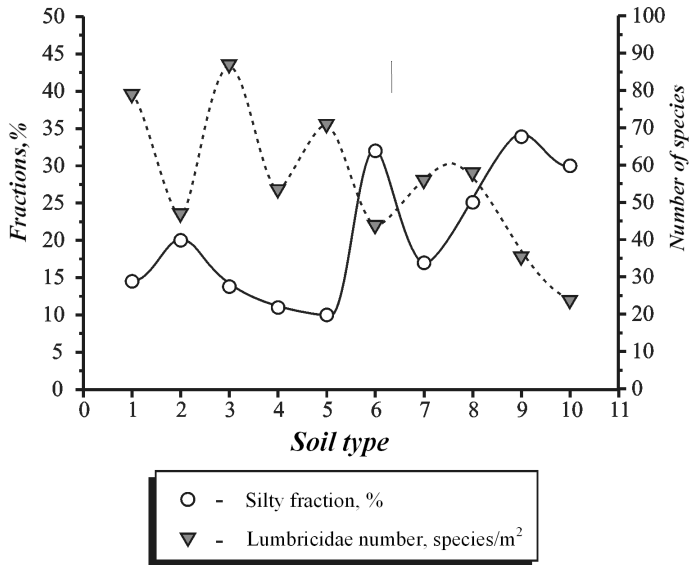


Fig. 2. The number of lumbricidae (specimen/m²) according to the content of the silty fraction in edaphotopes of Western Volyn and Podillya. Explanations as in Fig. 1.

In typical chernozems, there is a tendency for further deepening of the granulometric composition change. The content of physical clay reaches 59% and that of sand up to 41%. Actual acidity is neutral. The lumbricidae complexes are represented by six species; their number is 37 ± 5.1 sp. m⁻² (Fig. 2). The least favourable conditions for earthworm invasion are in typical low humus chernozems and wet typical chernozems. Physical clay, as compared to podzolic chernozems, has a high content of the silty fraction (33.9%) in the humus horizon. High content of the silty fraction in the horizons of the soil profile has influenced the formation of the soil oligochaete complex of typical low-humus chernozems and wet typical chernozems.

CONCLUSIONS

1. The genesis of earthworm complexes of Western Volyn and Podillya is conditioned by the granulometric composition of soils and its processes.
2. The structure of earthworm complexes is associated with the qualitative spectrum of granulometric functions. Basically, oligochaete complexes of Western Volyn and Podillya are adapted to grey forest soils with the optimal value of the silty fraction within 18–20%.
3. The increase in the silty fraction in chernozems leads to the degradation of earthworm complexes and reduction of qualitative values.

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WPŁYW SKŁADU GRANULOMETRYCZNEGO GLEB NA WYSTĘPOWANIE DŹDŻOWNIC

W pracy przedstawiono wpływ rozkładu frakcji granulometrycznych różnych poziomów genetycznych gleb na cechy jakościowe i ilościowe dżdżownic. Stwierdzono istotny wpływ udziału różnych frakcji granulometrycznych w kształtowaniu wilgotności, temperatury, stanu gazowego i aktualnej kwasowości gleb, jako podstawowych czynników abiotycznych, w genezie zespołów dżdżownic w glebach Zachodniego Wołynia i Podola.