CHANGES IN SOIL BIOTA AND ITS RELATIONSHIPS WITH SOIL PROPERTIES ACROSS DIFFERENT LAND-USE TYPES

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Abstract

The purpose of this paper was to determine the changes in soil biota from typical chernozems across different land-use types, as well as to determine its interdependence with the soil properties. In the paper were investigated loamy-clayey typical chernozems in the following variants: arable; 15 years under the fallow; 60 years under the fallow. It was established that the parameters of the biological indices decrease on the soil profile with the depth. It was observed that in arable soils the main fauna mass is concentrated in the layer 20-60 cm. Also, due to the strong compaction of these soils, there is an abrupt decrease in the number of invertebrates and the change of microfauna structure. The content of microbial biomass gradually decreases with depth in all studied soil profiles. There is a significant decrease of the microbial biomass content in arable chernozems compared to the other soils. These values range from 280.7 µ g C g^{-1} soil in the 0-25 cm layer to 217.8 µ g C g^{-1} soil in the 35-50 cm layer. Due to the lower number of bacteria, actinomycetes and fungi in arable soils, there is a considerable prevalence of microorganisms decomposing humus. Interaction of soil biota and its metabolites with soil vegetation leads to structure improvement, formation of valuable agronomic aggregates and increase of their hydrostability. A close correlation between the biomass indices, the number of microorganisms and the structure of typical chernozems in the former 0-25 cm arable layer was found, where the restoration process is more intense, the layer being degraded more strongly. Analogic legitimacy was detected for microbiological indices and water stable aggregates content and structuring coefficient.

Key words: soil degradation, biological indices, correlation, humus content, soil structure

Microorganisms play an enormous role in soil life. They decompose organic residues, form and mineralize the humus in the soil, implicitly supplying plants with nutrients by transforming inaccessible forms of nitrogen, phosphorus and potassium into accessible forms. The level of soil fertility is closely related to the activity of microorganisms, which is predominantly takes place on the surface of the soil particles. The particle surface can reach values up to several square meters per gram of soil (Zveaghintsev D.G., 1985). Also, microorganisms participate in pedogenic processes by disaggregating parental minerals and forming new minerals (Netrusov A.I., 2004). They influence soil reaction, nutrient dynamics and the conversion of pollutants and toxic substances.

The activity and number of microorganisms are closely related to organic matter content in soils. According to Ghilearov's data, one gram of chernozem contains 2-2.5 billion of bacteria (Ghilearov, 1978).

The use of soils in agriculture leads to the degradation of their fertility and quality. The anthropogenic influence on soils is manifested by the appearance of such processes as humus and soil structure loss, depletion of nutrients etc., which is explained by the intensification of the microbiological processes, which in large part determines the character of the biological circuit. In this conditions the microorganisms that participate in mineralization of organic substances and transformation of nitrogen-containing substances (Muha V.D., 1988; Muha V.D., 2003; Sheglov D.I., Brehova L.I., 2003) develop most intensively.

In these conditions, it is necessary to investigate the changes occurring in the arable soils' biota and its relationship with the soil properties in dependence of land use types in order to ensure sustainable soil use, prevent further soil degradation and enhance soil properties and fertility.

MATERIAL AND METHOD

The research was conducted on experimental fields of the Research Institute of Field Crops "Selectia" from Balti, Republic of Moldova. We investigated loamy-clayey typical

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chernozems in the three following variants: arable; 15 years under the fallow; 60 years under the fallow. The investigated soils have the following characteristics:

1. Arable loamy-clayey typical chernozems: humus content - 4.03% (0-25 cm layer), 3.81% (25-35 cm layer), 3.01% (35-50 cm layer); total nitrogen - 0.22%, 0.21%, 0.17%; total phosphorus - 0.13%, 0.12%, 0.10%; pH - 6.3; 6.4; 6.5; bulk density - 1.10; 1.43; 1.36 g/cm^3, total porosity - 58.0; 45.3; 48.7% respectively. The soils are characterized by a good structure for the 0-25 cm layer and unsatisfactory for the next layer (25-35 cm), bulk density is satisfactory, the layer 25-35 cm is strong compacted.

2. Loamy-clayey typical chernozems 15 years under the fallow: humus content - 5.47% (0-10 cm), 4.54% (10-25 cm), 4.00% (25-35 cm), 3.43% (35-50 cm); total nitrogen - 0.30%, 0.25%, 0.22%, 0.19%; total phosphorus - 0.15%, 0.13%, 0.12%, 0.11%; pH - 6.9; 6.8; 6.7; 6.8; bulk density - 1.22; 1.36; 1.41; 1.37 g/cm^3, total porosity - 53.3; 48.4; 46.8; 48.5% respectively. The soils are characterized by excellent grain structure, optimal values of bulk density, the former compacted layer of 25-35 cm is almost restored by influence of plants roots.

3. Loamy-clayey typical chernozems 60 years under the fallow: humus content - 6.70% (0-10 cm layer), 5.94 (10-28 cm layer), 4.23 (28-49 cm layer); the total nitrogen content is 0.35%, 0.31%, 0.22%; total phosphorus - 0.13%, 0.11%, 0.09%; pH - 6.8; 6.9; 7.1; bulk density - 1.13; 1.30; 1.31 g/cm^3, total porosity - 56.5%, 50.2%, 50.2%, respectively. Soils are characterized by excellent grain structure and optimal bulk density values.

The status of invertebrates was determined by manually sampling the soil layers to the depth of soil fauna occurrence by Gilyarov and Striganova's method (Gilyarov and Striganova, 1987). The microbial biomass was measured by the rehydratation method based on the difference between C extracted with 0.5 M K_2SO_4 from dried soil at 65-70°C in 24 h and fresh soil samples with Kc coefficient of 0.25 (Blagodatsky *et al*, 1987). The K_2SO_4 – extractable organic C concentrations in the dried and fresh soil samples were simultaneously measured by dichromate oxidation. The quantity of K_2SO_4 – extractable C was determined at 590 nm using a spectrophotometer. Counts of humus-mineralizing microorganisms were obtained on agar plates (Zvyagintsev, D.G., 1991). Sampling was carried out from the 0-30 cm layer.

RESULTS AND DISCUSSIONS

Soil fauna. Typical chernozems are characterized by the highest values of number, diversity and biomass of soil fauna in comparison with other chernozem subtypes from the Republic of Moldova. For heavy compacted anthropic degraded soil a sudden decrease in the number of invertebrates and the change of microfauna structure are characteristic. On average, the total number of invertebrates in typical arable chernozem was 104 ex m^{-2}, in typical chernozem 15 years under the fallow – 288 ex m^{-2}, in typical chernozem 60 years under the fallow – 292 ex m^{-2}. Number of *Lumbricidae* family was – 60, 122 and 204 ex m^{-2} respectively (*figure 1*).

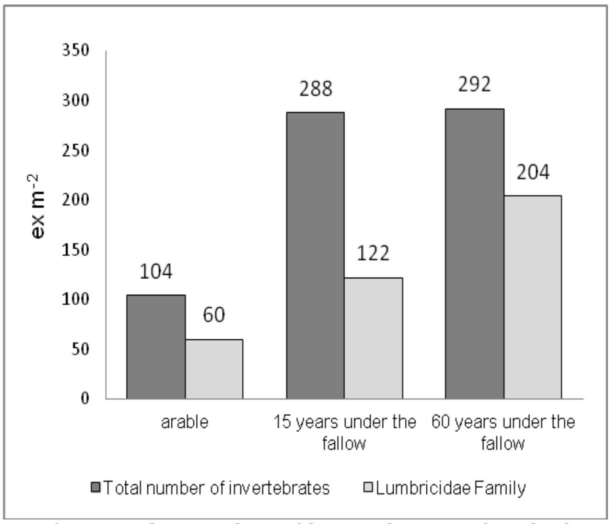

Figure 1 **The number of invertebrates of typical chernozems with a full profile under different land use**

Total biomass of invertebrates is similarly distributed in studied variants of land-use types – 12.2; 48.4 and 62.0 g m^{-2}; biomass of *Lumbricidae* family is 11.0; 11.6 and 26.0 g m^{-2} respectively (*figure 2*).

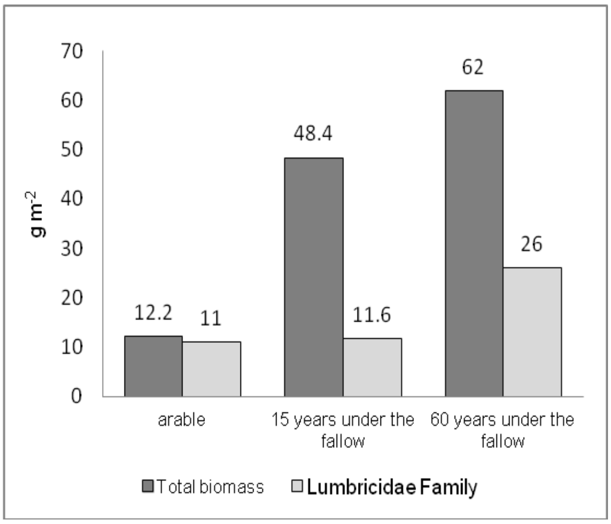

Figure 2 **The biomass of invertebrates of typical chernozems with a full profile under different land use**

Distribution of invertebrates in soil profile of arable and fallow soils is different. In the arable soil the main mass of the fauna is concentrated in the layer 20-60 cm. There was no fauna found in the layer 0-10 cm, because that layer is regularly worked. In the soils 15 and 60 years under the fallow, the invertebrates are concentrated in the upper layer. Their number and biomass decreases in profile to a depth of 60 cm in variant 15 years under the fallow and up to 30 cm in soil 60 years under the fallow (*figure 3*).

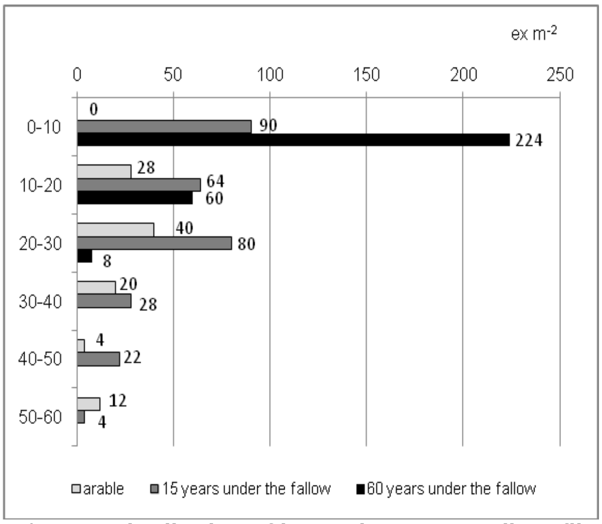

Figure 3 **Distribution of invertebrates on soil profile in typical chernozems in dependence of land use**

Fauna of typical arable chernozem is predominantly represented by the *Lumbricidae* family. Fallow soils have a greater diversity of invertebrates. Besides the *Lumbricidae* family, in fauna samples were found species from other families, such as *Farmica, Enchytraeidae, Elateridae, Carabidae, Chilopoda, Diplopoda* families. Mollusca species were also present. Investigations of typical chernozems across different land-use types demonstrated and confirmed that long-term use of soils under the arable leads to degradation of soil fauna complex. Soils 15 and 60 years under the fallow, due to natural conditions created by steppe vegetation, restored the number and diversity of invertebrate species, as well as their biomass.

Microbial biomass. The microbial biomass content normally decreases by depth in all studied soil profiles. Its average content in typical arable chernozem decreases with depth from 280.7 μ g C g^{-1} soil in the layer 0-25 cm to 217.8 μ g C g^{-1} soil in the 35-50 cm layer. In case of typical chernozem 15 years under the fallow total microbial biomass decreases from 419.8 μ g C g^{-1} soil in the 0-10 cm layer to 243.3 μ g C g^{-1} soil in the 35-50 cm layer. The maximum microbial carbon content was found in typical chernozem 60 years under the fallow, where this value constituted 501.1 μ g C g^{-1} soil in the upper 0-10 cm layer (*figure 4*).

The main reserves of microbial carbon in arable soils are concentrated in the 0-25 cm layer, where the main microbial biomass is concentrated because of more favorable living conditions (in comparison with the next compacted soil layer 25-35 cm). In fallow soils, the reserves of microbial carbon are found in 0-10 cm, 10-25 cm and 25-35 cm layers.

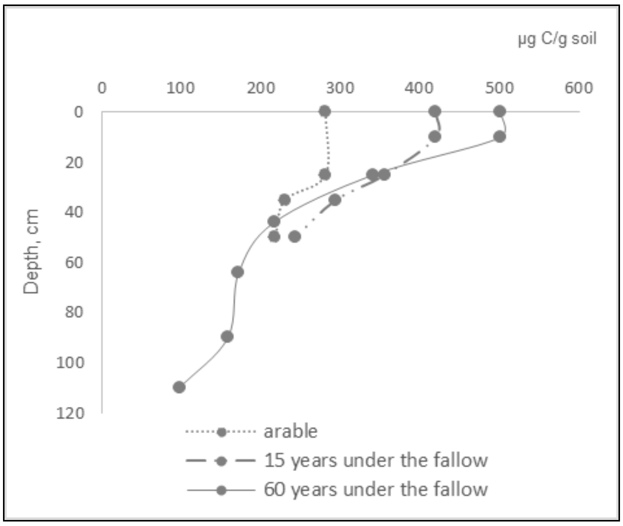

Figure 4 **The content of microbial biomass in typical chernozems with full profile in dependence of land use**

Total microbial biomass for the 0-50 cm layer of studied soils is the next: arable typical chernozem – 2640.6-3406.9 kg/ha (in average 3087.1 kg/ha); typical chernozem 15 years under the fallow – 3760.2-4665.4 kg/ha (in average 4306.2 kg/ha); typical chernozem 60 under the fallow – 3823.5 kg/ha (for a profile).

Number of microorganisms. The number of microorganisms and their biomass in all studied profiles of typical chernozems decreases with depth. At the same time, a significant increase of the ratio *bacteria:fungi* is observed: in arable soil from 360 to 477, in chernozem 15 years under the fallow from 168 to 287, in soil 60 years under the fallow from 221 to 544 (*table 1*).

Structure of microbial associations changes in dependence of land-use type. Arable soil is characterized by lower number of bacteria, which assimilates the mineral nitrogen, actinomycetes and fungi. Here prevail microorganisms that decompose humus. For comparison, in the chernozem 15 years under the fallow their content in average makes 6.8 mln g^{-1} in the layer 0-10 cm and 3.6 mln g^{-1} in the layer 10-25 cm, but in the typical arable chernozem the content is 16.9 mln g^{-1} in layer 0-25 cm, which is 3.3 times more.

The ratio of bacteria to fungi decreases from typical arable chernozem to chernozem 15 years under the fallow in all genetic horizons: from 360 in the Ahp1 horizon (0-25 cm layer) to 168-174 of the Ahpţ1 horizon (0-10 cm layer) and Ahp2 (10-

25 cm layer); From 374 in the Ahp2 horizon (25-35 cm layer) to 234 in the Ahp horizon (25-35 cm layer); From 477 to 287 in the Ah horizon (35-50 cm layer). The variability of the number of microorganisms is insignificant. The coefficient of variation is 1.6-11.2% depending on the soil genetic index.

Table 1

The number of microorganisms in typical chernozems with a full profile in dependence of land use

Genetic horizon and soil depth, cm		Humus decomposing microorganisms	Bacteria assimilable of mineral nitrogen	Actinomycetes	Fungi, thousands /g soil	Ratio Bacteria : Fungi
		mln/g soil				
Arable loamy-clayey typical chernozems						
Ahp1	0-25	16.9	8.2	3.2	32	361
Ahp2	25-35	8.9	5.3	2.8	22	374
Ah	35-50	2.2	3.0	1.5	10	477
Loamy-clayey typical chernozems 15 years under the fallow						
Ahpţ1	0-10	6.8	11.8	4.5	97	168
Ahpţ2	10-25	3.6	10.1	3.1	76	174
Ahp3	25-35	2.4	7.4	2.9	44	234
Ah	35-50	1.6	4.2	1.4	19.4	287
Loamy-clayey typical chernozems 60 years under the fallow						
Ahţ1	0-10	4.7	18.4	2.8	96	221
Ahţ2	10-25	2.2	7.6	1.5	16	569
Ah	25-44	1.4	3.8	1.1	9	544
Bh1	44-64	0.5	0.7	0.2	5	180
Bhk2	64-90	0.3	0.3	0.1	1	400
BCk1	90-110	0.1	0.2	0.03	0	-

Interaction of soil biota and its metabolites with soil vegetation leads to improved structure, formation of agronomic valuable aggregates, and increased water stability. The content of agronomic valuable aggregates (Σ 10-0,25 mm) in the 0-25 cm layer increases from 59,2% on arable soils to 89,4-95,9% on fallow soils. Content of particles >10 mm and <0.25 mm decreased from 40.8% to 4.2-5.4%, respectively. The quantity of water stable aggregates increased from 65.9% to 79.6 - 80.2%. Structuring coefficient increased from 1.5 to 9.5-30.9. As a result, soil resistance to anthropogenic action and soil quality increased.

The correlation analysis of the interdependence between the microbiological indices on the one hand and the humus content and bulk density on the other showed their close relationship. The correlation coefficient (R^2) between biomass and the number of microorganisms and the humus content are: on typical arable chernozem R^2 = 0.58-0.90; on typical chernozem 15 years under the fallow R^2 = 0.76-0.95; on chernozem 60 years under the fallow R^2 = 0.74-0.94. The correlation coefficient between the microbiological indices and bulk density in these soils is R^2 = - 0.47 - (-0.74); R^2 = -0.55- (-0.73); R^2 = -0.96 - (- 0.99) respectively. Thus, a medium and strong positive relationship with the humus content was established. Relationship with bulk soil density is medium and strong negative. The correlation dependence increases from the arable soil to the fallow soils.

We established an increase of the link between microbial indices and the content of agronomic valuable and water stable aggregates in the row: arable chernozem, chernozem 15 years under the fallow, chernozem 60 years under the fallow. In arable soils, this connection is weak, while in soils 15 and 60 years under the fallow - medium and strong.

A close correlation was established among the biomass indices, the number of microorganisms and the soil structure of the typical chernozems in the layer (0-25 cm), where the restoration processes are more intensive (*table 2*).

Correlation coefficient (R^2) with the sum of agronomic valuable aggregates is 0.86-0.92; with sum of fractions >10 mm and <0,25 mm - 0,86 - (-0,92) respectively. Analogical pattern was also found for microbiological indices in relation with water stable aggregates content and the coefficient of structure. The effect of the interaction decreases with the depth on the soil profile.

Table 2

The correlation coefficient (R2*) between the microbiological indices and the content of the structural aggregates in the typical chernozem under different land use types (the 0-25 cm layer)

Index	Aggregates content (%) with diameter (mm)											Ks**
	>10	10-7	7-5	5-3	3-2	2-1	1-0,5	0,5-0,25	<0,25	∑10-0,25	∑ >10+<0,25	
Dry sieving												
Microbial biomass, $\mu g C g^{-1}$	-0.85	-0.16	0.56	0.9	0.82	0.81	-0.13	0.11	-0.19	0.86	-0.86	0.74
Bacteria assimilable of mineral nitrogen, mln/g soil	-0.92	-0.2	0.55	0.95	0.86	0.01	0.19	0.2	-0.11	0.92	-0.92	0.89
Actinomycetes, mln/g soil	-0.30	0.48	0.62	0.03	0.07	0.22	0.14	0.29	0.26	0.27	-0.27	-0.37
Fungi, thousands/g soil	-0.89	0.13	0.78	0.75	0.74	0.78	0.18	0.38	0.11	0.87	-0.87	0.43
Wet sieving												
Microbial biomass, $\mu g C g^{-1}$	–	–	–	0.51	0.54	0.61	-0.31	-0.72	-0.78	0.78	-0.78	-
Bacteria assimilable of mineral nitrogen, mln/g soil	–	–	–	0.63	0.64	0.16	-0.48	-0.74	-0.91	0.91	-0.91	-
Actinomycetes, mln/g soil	–	–	–	0.45	-0.33	0.3	-0.09	-0.19	-0.41	0.41	-0.41	-
Fungi, thousands/g soil	–	–	–	0.79	0.34	0.59	-0.44	-0.72	-0.93	0.93	-0.93	-

R^2 – correlation coefficient

** Ks – coefficient of structure

- Strong positive correlation
- Strong negative correlation

We established that total microbial biomass is predominantly located in agronomic valuable aggregates: in fractions 5-3, 3-2, and 2-1 mm, partly in the 7-5 mm fraction. Bacteria occupy fractions of 5-3, 3-2 mm, and partially 7-5 mm. Fungi have a strong positive correlation with fractions 7-5, 5-3, 3-2 and 2-1 mm. These, due to the micellar system, participate in the formation of water stable aggregates of 5-3 mm size (R^2 = 0.79). The relationship of actinomycetes with agronomic valuable aggregates doesn't exist or is very weak, except for the fraction 7-5 mm (R^2 = 0.62).

The results have shown that the interaction between microbial components (and biota in general) and structural state and soil fertility is stronger in the fallow soils, especially in the 0-25 cm layer. As a result, their resistance to anthropogenic and natural negative actions is higher than of soils involved in agriculture.

CONCLUSIONS

1. By most zoofaunistic and microbiological indices, the investigated soils can be arranged in ascending order in the following way: arable typical chernozem → typical chernozem 15 years under the fallow → typical chernozem 60 years under the fallow.

2. Parameters of biological indices decrease on soil profile by depth and are characterized by a close positive relationship with the humus content and the strong negative relationship with the bulk density of the soil. Correlation coefficients are 0.58-0.95 and -0.48 - (- 0.99), respectively.

3. Interaction of soil biota and plants root system in typical chernozems led to soil structure improvement. The closest relationship between microbiological indices and soil structural state was found in the 0-25 cm layer. A strong positive

correlation was found between the abundance of microorganisms and the sum of agronomic valuable aggregates (10-0.25 mm), R^2 = 0.86-0.92. Microbial biomass is located in fractions 5-3, 3-2, 2-1 mm, and partly in the 7-5 mm fraction. The relationship between the microbial complex and the sum of fractions >10 mm and <0.25 mm is strongly negative, R^2 = -0.86 - (-0.92). The formation of water stable aggregates was influenced mainly by the presence of microscopic fungi in the soil (R^2 = 0.79).

4. Typical chernozems 15 years under the fallow had an annual increase in microbial carbon content by 81.3 kg of dry matter per hectare in the 0-50 cm layer and restoration of population of invertebrates and microorganisms. Typical chernozems under the fallow are oases for preserving and restoring soil biota.

ACKNOWLEGMENTS

The research was carried out with the financial support of the Agency of Land Relations and Cadastre and the Republican State Association for Soil Protection, project no. 14 "Introduction of Soil Quality Monitoring".

We thank our colleagues from the Institute of Pedology, Agrochemistry and Soil Protection “Nicolae Dimo”, namely laboratory of Pedology and research group of Microbiology, who provided insight and expertise that greatly assisted the research.

We would also like to show our gratitude to the Mr. Cerbari Valerian, doctor habilitatus, professor, head of laboratory of Pedology, Institute of Pedology, Agrochemistry and Soil Protection “Nicolae Dimo”, for sharing his pearls of wisdom with us during the course of this research.

REFERENCES

Blagodatsky, S.A., Blagodatskaya, E.V., Gorbenko, A. J., Panikov, N. S., 1987 - *Rehydration method for the determining of the microbial biomass in the soil,* Pochvovedenie, Moscow, Russia, 4, p. 64–71.

Ghilearov M.S., Striganova B.R. *Role of soil invertebrates in decomposition of plant residues and circulation of substances.* In: Zoology of invertebrates, Moscow, 1978, part 5.

Muha V.D. *Anthropic factor in soil formation.* In: Challenges of soil evolution. Materials of IV Conference. Pushino, 2003, p. 191-201.

Muha V.D. *The main characteristics of soil evolution.* In: Natural and anthropogenic soil evolution. In: Collection of scientific articles. Pushino, 1988, p. 100-107.

Netrusov A.I. (Ed.), *Ecology of microorganisms.* Moscow: Academy, 2004. – 272 p.

Sheglov D.I., Brehova L.I. *Evolution of chenozems of central Russia in conditions of contemporary pedogenesis.* In: Challenges of soil evolution. Materials of IV Conference. Pushino, 2003, p. 244-247.

Zveaghintsev D.G. *Soil and microorganisms.* Moscow: MGU, 1985

Zvyagintsev, D.G. (Ed.), 1991 - *Methods of soil microbiology and biochemistry.* Moscow, Russia, MSU, 304 p.