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IRECTION AND STRENGTH OF MICROBIOLOGICAL PROCESSES IN LAYERS OF GRAY FOREST SOIL UNDER DIFFERENT REGIMES OF MANAGEMENT

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The aim of the work was to study the direction and intensity of mineralization and immobilization processes in different layers of gray forest soil at fallow fields, extensively and intensively used agrosoils. The research included laboratory analysis, microbiological studies, and statistical processing. For the fallow plots, the layers chosen for study were Hd — turf (0–10 cm), He — humus-eluvial (11–40 cm), Hi — humus-illuvial (41–74 cm), Ih — illuvial-humus (75–115 cm), Ip — transitional from the illuvial layer to bedrock (116–156 cm), Pi — bedrock with occasional insertions of illuvial soil (157–191 cm); for the agrosoils of the stationary experiments: He — humus-eluvial (0–10 and 11–40 cm), Hi — humus-illuvial (41–74 cm), Ih — illuvial-humus (75–115 cm), Ip — transitional from the illuvial layer to bedrock (116–56 cm). We found that humus mineralization differed in some layers of the gray forest soil under these management regimes. At fallows, the intensity of humus mineralization tended to decrease with depth, and it was interrupted in the Ih and Ip layers. In the intensively used agrosoil, humus mineralization was more active in Hi- and Ih-layers. Comparatively, the activity of humus mineralization smoothly decreased in the profile of the extensively used agrosoil from the uppermost layer to the lower by 97.2%. The mineralization coefficient of Nitrogen compounds gradually decreased in the fallow ground and extensively used agrosoil, unlike the intensively managed agrosoil, in which the intensity of mineralization-immobilization of nitrogen compounds increased in the He and Hi layers. It was shown that the fallow ground had the more efficient system to transfer substrates and mineral ions down the profile to the lower layers. The difference in biologic activity between the upper and lower layers was maximum in the fallow ground, intermediate in the intensively used agrosoil and minimum in the extensive agrosoil.

Key words: soil horizons, index of pedotrophy, nitrogen mineralization coefficient, humus mineralization activity, fallow ground, agrosoil.

Research of the microbial distribution along the soil profile gains weight considering that the microbial biomass is relatively evenly distributed across the whole cross-section of the gray forest soil, turf podzol, chernozem, kastanozem [1] and peat [2, 3]. Vertically layered microbial communities are viewed as integral components of ecosystems [4]. For every layer of the ecosystem, there are specific ranges of both quantity and taxonomic diversity of the microorganisms. For every type of soil, the maximum quantity and taxonomic diversity of the bacterial complexes are seen in the litter, minimum in the mineral horizon. The main factor determining the quantities and diversity of prokaryotes is type of substrate (layer position). Biotope features and seasonal characteristics have much lower influence [3, 4].

Materials and Methods

The study was done on gray forest soil at closely situated plots: 1 — soil excluded from agriculture use in 1987; 2–3 — agrosoils of the stationary experiment that was started in 1987 on the territory of the experimental station "Chabany" in Kyiv-Svyatoshynskyi district of Kyiv region. We studied versions with a ground development scheme that is traditional for Forest-Steppe: 2 — control, crop rotation without additional mineral and organic fertilizer (extensively used agrosoil); 3 — crop rotation with additional mineral fertilizer N_{96} P108 K112.5 and conventional tillage of agricultural side products (intensive agrosoil).

Soil samples were taken from such horizons of the fallow ground: Hd — turf (0–10), He — humus-eluvial(11–40 cm), Hi — humus-illuvial (41–74 cm), Ih — illuvial-humus (75–115 cm), Ip — transitional from illuvial to bedrock (116–156 cm), Pi — bedrock with insertions of soil from the illuvial horizon (157–191cm). For agrosoils, the sampled horizons were: He — humus-eluvial (0–10 and 11–40 cm), Hi — humus-illuvial (41–74 cm), Ih — illuvial-humus (75–115 cm), Ip — transitional from the illuvial horizon to bedrock (116–156 cm).

The mineralization intensity of nitrogen compounds was calculated after Ye. N. Mishustin and E.V. Runov [5], the index of pedotrophy after D. I. Nikitin and V. S. Nikitina [6], the activity of humus mineralization – after I. S. Demkina and B. N. Zolotaryova [7]. To make a general assessment of the biologic state of soil, we calculated the parameter of overall biologic activity (OBA) using the method of relative valuation [8, 9].

Results and Discussion

Having analyzed the direction of microbiological processes in soil by the mentioned parameters and indices, we found that the intensity of mineralization processes changes depending on the position of the sample along the profile (Tables 1–3). Thus, indices of pedotrophy are somewhat lower for soil from the upper horizons of fallow ground and intensive agrosoil than from the He horizon, perhaps due to lesser humidity of the soil. The intensity of the organic matter mineralization decreased by 47.1% in the upper horizon of fallow field. For the intensive agrosoil it decreased in 4.18 times. For extensive agrosoil the trend was reversed: the mineralization activity was higher precisely in the upper horizon. This provides additional evidence about the relatively more similar soil processes in the intensive agrosoil and the fallow ground.

The activity of the organic matter decomposition sharp decreased at the edge of the Hi horizon by 4.92 times for the fallow field and by 3.03 times for the intensive agrosoil. In the extensive agrosoil the index of pedotrophy conversely increased by 87.4%. Such difference underscores the significant consequences of different intensity of soil management. The highest mean activity of the organic matter utilization in the arable horizon was seen in the intensive agrosoil (0.989), then the fallow field (0.546) and extensive agrosoil (0.434).

Nitrogen mineralization coefficient gradually decreased in fallow soil from 0.254 (upper horizon) to 0.072 (lowest of the studied horizons) (Table 1), the same tendency was seen in extensively used agrosoil (Table 3). However, in the intensively used agrosoil the intensity of mineralization-immobilization of Nitrogen compounds was higher in horizons He and Hi, perhaps due to migration of Nitrogen mineral compounds to the layer of

Table 1. **Intensity of mineralization processes and phytotoxic properties of gray forest soil used for fallow since1987**

Horizon / depth	Index of pedotrophy	Oligotrophy coefficient	Nitrogen mineralization coefficient	humus mineralization activity , %	Total bioactivity, %	Kr	Mass of 100 plants of the test culture, winter wheat, g		
							stem	root	total mass
Hd (0–10)	0.221	0.037	0.254	21.2	2264.0	0.352	8.08	13.9	22.0
He(11–40)	0.325	0.039	0.242	20.1	2249.8	0.341	8.46	7.34	15.8
Hi (41–74)	0.066	0.005	0.109	9.26	1184.0	0.140	9.57	10.4	20.0
Ih (75–115)	0.029	0.007	0.139	27.2	382.6	0.018	7.87	9.53	17.4
Ip (116–156)	0.014	0.003	0.025	49.8	344.8	0	6.80	6.90	13.7
Pi (157–191)	0.029	0.010	0.072	6.10	100	0	8.08	8.32	16.4
HIP05							0.11	0.12	

Table 2. **Intensity of mineralization processes and phytotoxic properties of gray forest soil managed as intensively used agrosoil since 1987**

Horizon / depth	Index of pedotrophy	Oligotrophy coefficient	Nitrogen mineralization coefficient	Humus mineralization activity, %	Total bioactivity, %	Mass of 100 plants of the test culture, winter wheat, g		
						stem	root	total mass
He (0–10)	0.191	0.100	0.160	25.7	1460.0	8.73	4.84	13.6
He (11–40)	0.798	0.744	0.621	23.8	962.0	6.54	4.77	11.3
Hi (41–74)	0.263	0.173	0.048	59.6	466.0	4.65	4.76	9.41
Ih (75–115)	0.119	0.299	0.155	42.6	147.9	4.31	5.57	9.88
Ip (116–191)	0.202	0.166	0.274	24.0	100.0	4.62	5.58	10.2
HIP05						0.13	0.10	

Table 3. **Intensity of mineralization processes and phytotoxic properties of gray forest soil managed as extensively used agrosoil since 1987**

Horizon / depth	Index of pedotrophy	Oligotrophy coefficient	Nitrogen mineralization coefficient	Humus mineralization activity, %	Total bioactivity, %	Kr	Mass of 100 plants of the test culture, winter wheat, g		
							stem	root	total mass
He (0–10)	0.252	0.16	0.37	21.1	864.2	4.28	6.5	5.89	12.4
He (11–40)	0.182	0.12	0.17	18.8	611.7	1.51	8.0	5.10	13.1
Hi (41–74)	0.341	0.22	0.045	17.5	159.7	4.28	4.33	4.66	8.99
Ih (75–115)	0.081	0.65	0.14	16.8	125.4	3.78	4.41	5.19	9.60
Ip (116–191)	0.390	0.33	0.46	10.7	100.0	2.80	4.44	4.01	8.45
HIP05							0.07	0.08	

11–74 cm (Table 2). The Nitrogen compounds mineralization coefficient increased in the lowest of the studied horizons in the extensively agrosoil to 0.456. It is impossible to explain by vertical migration of these compounds, because this agrosoil was not fertilized since 1987. Though, the ions may have migrated from the regularly fertilized plots of adjacent stationary experiments.

Humus mineralization activity gradually decreases down the profile; the trend is all the more clear in old fallow ground and extensively used agrosoil. Thus, the microbiological destruction of humus decreases between the upper and the lowest studied horizons by the factor of 3.5 in the fallow soil, and by the factor of 1.97 in extensively used agrosoil. Meanwhile, the decomposition of humus substances increased by 24.4–65.2 % in the layer of 41 to 115 cm compared to the upper and lower horizons in the fallow soil and intensive agrosoil. It could be caused by accumulation of mobile humus compounds in these soil layers (41–115 cm).

Agrochemical analysis showed that in fallow soil, the percentage of humus was

1.43% at He-horizon, 0.041% at Ih-horizon, and 0.018% at Pi-horizon [10]. This means that humus content between the horizons decreases by the factor of 34.9 and 79.4, respectively. The indigenous microflora decreased 10.5 and 200-folds, respectively, though the physiologic-biochemical activity of microorganisms in different horizons remained almost the same (11). Therefore, humus decomposition depends on many factors: humus content, concentration of easily utilized substrates and of macroelements which delay the mineralization of humus compounds, availability of oxygen, abundance of indigenous microorganisms and their physiologic and biochemical activity, etc.

Long-term research showed that the activity of humus mineralization was minimum in the first 20 cm of fallow soil and maximum in the extensive agrosoil [12]. In 2014, the humus mineralization activity decreased in the extensive agrosoil, perhaps due to overall lesser amounts of humus in it. For 27 years, no organic fertilizer has been added neither cover crop plowed under; the organic matter has been also taken out with the main crop leading to a significant decrease in humus content [13].

The comparison of different types of soil by microbial biomass and the comparison of soil horizons which strongly differ in humus do not confirm the dependence of microbial biomass on the amount of organic matter [1]. It can be caused by the microbial biomass not being wholly active, a large part staying dormant until the favorable stage of succession [14].

In the vegetation period of 2014, the phytotoxicity of fallow soil (horizon He) was the lowest, while that of the intensive agrosoil was 74.3% higher and of the extensive agrosoil — 92.7% higher than the in fallow soil. That agrees with long-term data [15[. In the arable layer, the difference was 64.7 and 61.4% (Tables 1–3). In the lowest of studied horizons (Ih) it was 84.9 and 68.8%, respectively, which also confirms that the fallow soil contains a system of capillaries which is absent (or imperfect) in agrosoils.

The total bioactivity, which is an integral parameter, was minimum in the lowest of studied horizons in all cases (Tables 1–3). The difference in bioactivity between the higher and the lower horizons is highest in the fallow soil (22.6 times). In the intensive agrosoil it was higher by 14.6 tomes, and in the extensive agrosoil the difference was minimum (by 8.64 times).

In this study, the total bioactivity of the gray forest soil was highest in the fallow soil. It exceeded the bioactivity of the intensive and extensive agrosoils in the upper horizon by 1.55 and 2.62 times, respectively. The total bioactivity in the fallow soil gradually decreased from the upper horizon Hd to He by 16.7%, from He to Hi by 90.0%, from Hi to Ih by 218.0%, from Ih to Ip by 8.44%, from Ip to Pi by 3.44 times (Table 1). In the extensive agrosoil, total bioactivity decreased between horizons by 44.6, 97.8, and 99.6%, respectively, and in the intensive agrosoil, by 23.7% between He (0–10 cm) and He (11–40 cm) and 3.39 times between He and Hi layers. The three lowest horizons all have almost identical total bioactivity (Table 3).

Same trend was observed at the arable layer (0–40 cm): the highest activity was seen in the fallow soil (2330.7), then the intensive agrosoil (2139.0) and the extensive agrosoil (2061.3), which agrees with previous data [12].

Hence, the direction and intensity of mineralization processes change across the soil profile. The specifics and scale of the change depend on soil use.

Conclusions

1. The fallow soil has the highest total bioactivity of all studied examples of management regimes of gray forest soil. The bioactivity in the upper horizon of fallow soil exceeds the values for the intensive and extensive agrosoils by the factors of 1.55 and 2.62, respectively. The difference in bioactivity between the upper and the lower horizons is highest in the fallow soil (22.6 times), moderate in the intensive agrosoil (14.6 times) and lowest in the extensive agrosoil (8.64 times).

2. The mineralization coefficient of nitrogen compounds gradually decreases in fallow soil and extensive agrosoil, but not in intensive agrosoil. In the last case, the intensity of mineralization-immobilization of nitrogen compounds increases in the He and Hi horizons, perhaps because of migration of mineral nitrogenous compounds to the 11–74 cm deep soil layer.

3. Humus mineralization activity is the highest in the two uppermost horizons of intensive agrosoil among the studied management regimes of gray forest soil. It does not decrease downwards along the soil profile unlike humus mineralization activity in the extensive agrosoil, where it gradually decreases along the profile.

4. In the fallow soil and intensive agrosoil, humus substances decomposition are more actively decomposed in the layer of 41–115 cm compared to higher and lower horizons by 24.4–65.2% , perhaps because of accumulation of mobile humus compounds in these specific soil layers.

5. The system of transport of substrates and mineral ions downwards to lower horizons is more efficient in the fallow soil, which is reflected by the change in phytotoxicity values.

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СПРЯМОВАНІСТЬ ТА НАПРУЖЕНІСТЬ МІКРОБІОЛОГІЧНИХ ПРОЦЕСІВ У ГОРИЗОНТАХ СІРОГО ЛІСОВОГО ҐРУНТУ ЗА ЙОГО РІЗНОЦІЛЬОВОГО ВИКОРИСТАННЯ

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Метою роботи було дослідження спрямованості та напруженості мінералізаційних процесів у ґрунті горизонтів сірого лісового ґрунту за його використання як перелогу, екстенсивного та інтенсивного агроземів. У дослідженні використовували лабораторно-аналітичний, мікробіологічний, статистичний методи. З'ясовували перебіг мінералізаційних та іммобілізаційних процесів у горизонтах сірого лісового ґрунту на перелогових ділянках: Hd — дернина (0–10 см), He — гумусово-елювіальний (11–40 см), Hi — гумусово-ілювіальний (41–74), Ih — ілювіально-гумусовий (75–115), Ip — перехідний від ілювіального горизонту до породи (116–156), Pi — порода із вкрапленнями ґрунту ілювіального горизонту (157–191 см) і на агроземах стаціонарного досліду: He — гумусово-елювіальний (0–10 і 11–40 см), Hi — гумусово-ілювіальний (41–74), Ih – ілювіально-гумусовий (75–115), Ip — перехідний від ілювіального горизонту до породи (116–56). Встановлено, що варіанти використання сірого лісового ґрунту відрізняються за активністю мінералізації гумусу в окремих горизонтах: у ґрунті перелогу простежується тенденція до зниження інтенсивності мінералізації гумусу вглиб профілю, що порушується у горизонтах Ih і Ip. В інтенсивному агроземі спостерігали підвищення активності мінералізації гумусу в Hi- і Ih-горизонтах, у профілі екстенсивного агрозему — плавне зниження активності мінералізації гумусу від верхнього горизонту до нижнього на 97,2%. Коефіцієнт мінералізації сполук азоту поступово знижувався в ґрунті перелогу й екстенсивного агроземy, на відміну від інтенсивного агроземy, де інтенсивність мінералізації-іммобілізації сполук азоту в горизонтах He і Hi підвищувалась. Показано, що ефективнішою системою транспортування субстратів і мінеральних іонів вглиб профілю до нижчих горизонтів характеризується ґрунт перелогу. Різниця в біологічній активності між верхнім і нижнім горизонтами була максимальною у ґрунті перелогу, середньою – в інтенсивному агроземі та мінімальною — в екстенсивному агроземі.

Ключові слова: горизонти ґрунту, індекс педотрофності, коефіцієнт мінералізації азоту, активність мінералізації гумусу, переліг, агрозем.

НАПРАВЛЕННОСТЬ И НАПРЯЖЕННОСТЬ МИКРОБИОЛОГИЧЕСКИХ ПРОЦЕССОВ В ГОРИЗОНТАХ СЕРОЙ ЛЕСНОЙ ПОЧВЫ ПРИ ЕЕ РАЗНОЦЕЛЕВОМ ИСПОЛЬЗОВАНИИ

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Целью работы было исследование направленности и напряженности минерализационных процессов в почве горизонтов серой лесной почвы при ее использовании как перегноя, экстенсивного и интенсивного агроземов. В исследовании использовали лабораторно-аналитический, микробиологический, статистический методы. Выясняли протекание минерализационных и иммобилизационных процессов в горизонтах серой лесной почвы на перегнойных участках: Hd — дерн (0–10 см), He — гумусово-элювиальных (11–40 см), Hi — гумусово-илювий (41–74), Ih — илювиально-гумусовый (75–115), Ip — переходный от илювиального горизонта до породы (116–156), Pi — порода с вкраплениями почвы илювиального горизонта (157–191 см) и на агроземах стационарного опыта: He — гумусово-элювиальных (0–10 и 11–40 см), Hi — гумусово-илювий (41–74), Ih — илювиально-гумусовый (75–115), Ip — переходный от илювиального горизонта к породе (116–56). Установлено, что варианты использования серой лесной почвы отличаются по активности минерализации гумуса в отдельных горизонтах: в почве перегноя прослеживается тенденция к снижению интенсивности минерализации гумуса вглубь профиля, которая нарушается в горизонтах Ih и Ip. В интенсивном агроземе наблюдали повышение активности минерализации гумуса в Hi- и Ih-горизонтах, в профиле экстенсивного агрозема — плавное снижение активности минерализации гумуса от верхнего горизонта к нижнему на 97,2%. Коэффициент минерализации соединений азота постепенно снижался в почве перегноя и экстенсивного агрозема, в отличие от интенсивного агрозема, где интенсивность минерализации-иммобилизации соединений азота в горизонтах He и Hи повышалась. Показано, что более эффективной системой транспортировки субстратов и минеральных ионов вглубь профиля к нижележащим горизонтам характеризуется почва перегноя. Разница в биологической активности между верхним и нижним горизонтами была максимальной в почва перегноя, средней — в интенсивном агроземе и минимальной — в экстенсивном агроземе.

Ключевые слова: горизонты почвы, индекс педотрофности, коэффициент минерализации азота, активность минерализации гумуса, перегной, агрозем.