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ECOLOGICAL ROLE OF LIVING ORGANISMS FOR FORMING OF TECHNOGENIC SOILS

EKOLOGICZNA ROLA ORGANIZMÓW ŻYWYCH W FORMOWANIU GLEB TECHNOGENNYCH

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Nikopol manganese basin is one of the biggest in Europe. It is situated in the South of Ukraine. Most of the mines in this basin are open-cast mines. Manganese ore mining here was accompanied by bringing out loam, red-brown and gray-green clay and various mixtures of Vi different minerals to the surface. That is why mining areas should be considered as shattered into small particles system, whose elementary soil particles are presented in various, unequal ratio. This conditions are conductive to development of complicated heterogeneous environment on terraces of open-cast mines.

Edaphotops of technogenic landscapes are characterized by very unfavorable physical, chemical and mechanical conditions. One of the most important characteristics, that distinguish them from zone soils is insignificant amount of nutrients for plants. Analysis of mineral samples indicates that ratio of accessible nitrogen in it is 0,50 - 1,24 mg/100g; ratio of mobile phosphorus is 0,31-1,80 mg and ratio of active potassium 24 - 64 mg/100g of mineral. Ratio of humus fluctuated between 0,05 - 0,95%. Nevertheless these areas are being used in agricultural production and are included into rotation of crops. In that case mining minerals themselves or mining minerals artificially covered with layer of fertile soil can be considered as insufficiently studied objects of man's agricultural activity . This explains the necessity to study them in details.

In Ukraine the research of biological reclamation of land, disturb by open-cast mining, was carried out by scientists of Chair of Soil Science and Ecology of Dniepropetrovsk State Agrarian University. The experiments were conducted in Dniepropetrovsk Region on the terraces of opencast mines of Alexandrovsk and Zaporozhye Basins. At first they were aimed on revealing the crops, best suited for cultivation on such edaphotops.

Reclamation of lands, disturbed by mining industry turned out to be a very difficult process.

The main reason for it is shortage of nitrogen in such lands. It is indicated by slow germination of crops of Poaceae, Poligonaceae, Chemopodiaceae and Cucurbitaceae families without proper nitrogen nutrition in ecotope. The duration of their growth and development depends on plants , biological peculiarities and their adaptability to severe soil and climatic conditions. As a rule they perish soon. The shortage of nitrogen in such lands can be compensated for only by legume crops, especially perennial legumes. The ability to assimilate atmospheric nitrogen enables these crops to produce almost the same yield on disturbed lands as on undisturbed arable lands (table 1).

TABLE 1

Productivity of some crops, cultivated on different edaphotops, quintals per hectare (q/h)

Variant	Crops				
	oat	peas	winter wheat	Medicago savita	Onobryhys arenaria
	total weight (weight of grain)			hay	
1. Undisturbed southern chernozem (zone soil)	35,4 (18,4)	30,2 (14,9)	(38,6)	31,5	28,0
2. Unfertilized layer of chernozem (thickness 40 centimeters)	33,0 (11,2)	24,7 (9,3)	(27,4)	25,5	26,9
3. Mixture of loam and sand:					
Without fertilizer	5,3 (1,2)	14,6 (7,5)	(2,1)	34,5	25,3
N_{80}	32,7 (9,3)	24,6 (9,3)	(10,5)	35,6	26,9
$P_{80}K_{80}$	9,3 (1,7)	24,8 (9,8)	(3,3)	41,5	33,2
$N_{80}P_{80}K_{80}$	45,4 (15,8)	33,9 (14,2)	(15,3)	43,6	36,7
4. Loam:					
Without fertilizer	11,4 (5,1)	16,4 (8,4)	(4,3)	33,0	29,9
N_{80}	43,5 (14,9)	30,0 (15,2)	(11,6)	34,1	31,0
$P_{80}K_{80}$	20,0 (7,2)	27,5 (11,0)	(5,0)	33,9	32,9
$N_{80}P_{80}K_{80}$	66,6 (21,3)	38,8 (19,8)	(18,2)	36,1	34,6
5. Red-brown clay					
Without fertilizer	-	-	-	31,3	21,0
$P_{80}K_{80}$	-	-	-	37,0	23,9
$N_{80}P_{80}K_{80}$	-	-	-	37,2	24,5
6. Gray-green clay:					
Without fertilizer	-	-	-	42,8	21,8
$P_{80}K_{80}$	-	-	-	46,3	23,5
$N_{80}P_{80}K_{80}$	-	-	-	48,2	23,1

Nevertheless, the main objective of land reclamation is not obtaining the maximum yields of cultivated crops but making soil creation process more intense and creating normal ecological conditions for surrounding territory . This long, grandiose and very complicated job can be done only by biological factor of soil creation process, first of all by plants' root systems and by microorganisms living on them; especially by roots of perennial legume grasses (Medicago sativa and Onobryhys arenaria). These crops were the pioneers of the terraces of open-cast mines in

Steppe Zone of Ukraine. Even under unfavorable weather condition they can form thick herbaceous covering on soil. They keep growing from early spring till late fall and provide upper arable layer of soil (40 cm) with a lot of nutrients after disintegration. No wonder that roots form 50-65% of total biological yield of these crops, while stems form only 15-36%, leaves and flowers
- 12-26%.

Under the same ecological conditions Onobryhys arenaria forms less roots than Medicago sativa (table 2). But root system of Onobryhys arenaria always works more efficiently then the one of Medicago sativa. This statement is proved by root productivity coefficient. For example in experiments on unfertilized mixture of soils root productivity coefficient was 0,58 and 0,28 respectively, that means that one weight unit of roots provided with nutrients 0,58 weight unit of overground parts of Onobryhys arenaria and only 0,28 - of Medicago sativa. Fertilizers enhanced root productivity coefficient to 0,62 and 0,31 respectively.

The same tendency was observed on other unfertilized edaphotops, where coefficient of root productivity was always lower than the one on fertilized edaphotops.

Root productivity coefficient of Medicago sativa and Onobryhys arenaria, cultivated on loam and artificially spread layer of chernozem, is always higher than the one of these crops, cultivated on clay. So, the poorer is edaphotop with nutrient and the worse are its physical and chemical conditions the more apparent becomes inverse proportion between weight of roots and root productivity coefficient.

In other words, the higher is ratio of roots in total biological yield, the lower is their productivity coefficient.

The positive role of legume crops is determined by peculiarities of their root systems, first of all by atmospheric nitrogen fixation. Besides, reaction of Medicago sativa and Onobryhys arenaria for ecological conditions of particular layers of open-cast mine terraces reveals itself also in high flexibility of their root systems. This flexibility implies creation of such quantity of roots of certain structure and allocation in soil that can supply plants with nutrients and produce the maximum possible yield under present ecological conditions. This, perhaps, is another unique biological peculiarity of Medicago sativa and Onobryhys arenaria that clearly reveals itself when these crops are cultivated on reclaimed lands and explains surprisingly high yields of hay that they produce.

As table 3 indicates, Medicago sativa and Onobryhys arenaria develop powerful root systems with huge length and surface on disturbed lands. More than that, they reply for scarcity of nutrients in edaphotop with augmentation of length and surface of roots. That means they create a lot of small roots searching for nourishment. And this fact is of significant importance. Root hair enlarges absorbing surface of root and allows it to intensify the process of absorbing nutrients.

For example, total length of Onobryhys arenaria roots on the area of one hector in upper 40-centimeter layer of unfertilized red-brown clay exceeded length of equator of our planet 2,5 times.

TABLE 2

The weight proportion ofhay to roots of Medicago sativa and Onobryhys arenaria (air-dry mass), gram/m^3

Variant	Total biological mass	Including:		Percentage of roots in total biological yield	Coefficient of productivity
		over-ground mass	under-ground mass		
1. Unfertilized layer of chernozem	906,4 / 1582,9	510,6 / 851,6	395,8 / 731,3	43,7 / 46,2	1,29 / 1,16
2. Fertilized $N_{80}P_{80}K_{80}$ layer of chernozem	1628,8 / 2163,1	985,0 / 1261,8	643,8 / 901,3	39,5 / 41,7	1,53 / 1,40
3. Unfertilized mixture of loam and sand	783,0 / 1595,0	287,0 / 345,0	496,0 / 1250,0	63,3 / 78,4	0,58 / 0,28
4. Fertilized $N_{80}P_{80}K_{80}$ mixture of loam and sand	1059,0 / 1829,0	404,0 / 436,0	655,0 / 1393,0	61,9 / 76,2	0,62 / 0,31
5. Unfertilized loam	868,6 / 1749,5	402,9 / 761,5	465,7 / 988,0	53,6 / 56,5	0,86 / 0,77
6. Fertilized $N_{80}P_{80}K_{80}$ loam	1400,8 / 1921,8	689,6 / 897,2	711,2 / 1024,6	50,8 / 53,3	0,97 / 0,88
7. Unfertilized red-brown clay	1121,9 / 1620,6	387,2 / 566,2	734,7 / 1054,4	65,5 / 65,1	0,53 / 0,54
8 Fertilized $N_{80}P_{80}K_{80}$ red brown clay	1225,6 / 1735,9	586,2 / 710,4	639,4 / 1025,5	52,2 / 59,1	0,92 / 0,69
9. Unfertilized gray-green clay	1407,4 / 1363,6	623,6 / 548,7	783,8 / 814,9	55,7 / 59,8	0,79 / 0,67
10 Fertilized $N_{80}P_{80}K_{80}$ gray-green clay	1528,6 / 1465,4	893,4 / 727,1	635,2 / 738,2	41,6 / 50,4	1,41 / 0,98

Note: Here and in table 3 numerator- Onobryhys arenaria, denominator - Medicago Sativa.

Flexibility can be seen in shape (silhouette, crown) of root system as well. It is particularly obvious when growing roots come across certain factor that limits their development. Roots immediately cease any interaction with it which is reflected in morphology of the entire root system. This is the reason why root system of plants, cultivated on reclaimed lands, grows in several tiers, usually starting from the depth of 50-60 centimeters. It means that lower layers of open-cast mine terraces contain more roots than upper layers. One can come across such phenomenon on the plots of land formed by minerals composed of particles of different sizes. For example, mixture of loam and sand. In this case, ecological conditions of environment are reflected not only in shape of underground but also overground parts of plant.

TABLE 3

Length and surface of root systems of three-year-old Medicago sativa and Onobryhys arenaria in 0-100 cm layer of soil, converting into 1 g of air-dry weight.

Variant	Mass of roots g/m^2	Surface of roots, cm^2	Length of toots, m
1. Undisturbed southern chernozem	309,0 677,8	101,3 70,6	11,9 7,6
2. Unfertilized artificially spread layer of chernozem	395,8 731,3	104,5 70,8	12,3 7,7
3. Fertilized $N_{80}P_{80}K_{80}$ artificially spread layer of chernozem	643,8 901,3	84,9 64,4	9,7 7,0
4. Unfertilized loam	465,7 988,0	122,8 68,3	14,8 7,2
5. Fertilized $N_{80}P_{80}K_{80}$ loam	711,2 1024,6	89,8 67,6	10,4 7,3
6. Unfertilized red-brown clay			
7 Fertilized $N_{80}P_{80}K_{80}$ red brown clay	734,4 1024,6	147,2 119,3	18,7 11,6
8. Unfertilized gray-green clay	639,4 1025,4	128,5 94,5	15,5 10,7
9. Fertilized $N_{80}P_{80}K_{80}$ gray-green clay	783,8 814,9	135,9 92,4	16,6 10,4
	635,2 738,3	129,8 79,3	15,7 8,7

Root system of plants always develops more intensively in layer 0-10 cm. That is why it tends to gravitate to land surface and its shape reminds of letter "T". This tendency inevitably occurred not only in variant with artificially spread layer of soil, but also in all other studied edaphotops: loam, mixture of loam and sand, red-brown and gray-green clay.

It is noteworthy, that 74-87% of roots is concentrated in upper 40-centimeters layer of any edaphotop. So, plants of Onobryhys arenaria develop 30-60 quintals of roots (air-dry weight) in arable layer on each hectare; plants of Medicago sativa- 62-84 quintals.

By interaction with solid phase of soil, roots convert these minerals into sites of biological activity . By all means, disintegration of such significant amount of organic material of legume crops is very conducive to intensification of new soil creation process. The reason for it is very simple: root system of, for example, Medicago sativa, cultivated on unfertilized loam, contains 115 kg/hectare of nitrogen, 19 kg of phosphorus, 34 kg of potassium and 85 kg/hectare of calcium. The content of nitrogen, phosphorus, potassium and calcium in roots of plants, growing on clay, is even greater.

Again, in 0-40 centimeter layer one plant of Medicago sativa, depending on nutrition, produces up to 43 nitrogen-fixing tubers; one plant of Onobryhys arenaria- up to 97 tubers. It is 1,5-4 times greater then in the same layer of undisturbed zone soil. Tubers contain extra 15-37 kg/hectare of nitrogen, 4- 7 kg of phosphorus, 6-8 kg of potassium and 15-37 kg/hectare of calcium.

According to the results of experiments, under conditions of techno gene landscapes of Steppe Zone of Ukraine root systems of, for example, Medicago Sativa, together with tuber bacteria and free-living nitrogen fixers, accumulate about 350 kg/hectare of nitrogen in 0-20 centimeter layer of soil every year . It is very high index that reflects ecological role of root systems of Medicago sativa and Onobryhys arenaria, cultivated on reclaimed soils.

Microorganisms also tend to concentrate in arable layer of soil (0-40 cm). They playa very important role in forming of fertile layers of soil. Even in unfertilized edaphotops, deprived of vegetable covering (table 4), the number of microorganisms was quite significant. However, their number in soil fluctuates a lot and depends on combined impact of environment components. Soil microorganisms are compelled to live in severe nourishment conditions. Microorganisms communities build their own complexes of particular physiological groups of organisms, that can find nutrients for stable development even under extreme conditions of open-cast mine terraces. Formed under impact of contrast ecological conditions the structure of microorganism community is fairly conservative and that is why numbers of particular groups of microorganism reflects biological activity of edaphotop. Anyway the maximum number of microorganisms occurs in spring, minimum number - in summer. The disintegration rate of vegetable remains depends on this number .

According to the results of experiments (table 5), roots of Medicago sativa, rich with easily accessible for microorganisms proteins, disintegrate faster than, for example, roots of wheat. Besides, maximum rate of root disintegration occurred in southern chernozem, minimum - in graygreen clay. Different rate of root disintegration of legume and cereal crops indicates the necessity to employ special rotations replete with Medicago sativa and Onobryhys arenaria in order to make technogene landscape biological. Only these crops can create diverse and active micro flora in arable layer of land, which is conductive to accumulation of soil fertility elements.

TABLE 4

Number of microorganisms in unfertilized edaphotops without vegetable covering.

Edaphotop	Depth of sample selection, cm	Number of microorganisms (millions per one gram of absolutely dry sample)
1. Undisturbed southern chernozem	0-20	104.2-12.6 / 56,3
	20-40	55.8-6.0 / 29,8
2. Artificially spread layer of chernozem	0-20	82,7-10,1 / 44,9
	20-40	21,8-6,4 / 12,7
3. Loam	0-20	18,2-3,8 / 10,3
	20-40	5,4-1,7 / 3,3
4. Red-brown clay	0-20	19,8-7,2 / 12,3
	20-40	6,8-1,7 / 4,0
5. Gray-green clay	0-20	38,6-7,3 / 21,7
	20-40	9,1-2,6 / 5,7

Note: numerator - maximum and minimum possible values, denominator - average value.

Root disintegration rate is the highest during first three month, when there are a lot of microorganisms in soil and they can find easily accessible elements in vegetable remains. Afterwards disintegration process becomes slower.

TABLE 5

Root disintegration rate of Medicago sativa and Onobryhys arenaria.

Name of edaphotop	Percentage of distengrated rates after		
	3 month	10 month	12 month
Undisturbed southern chernozem	58.7 (49.2-64.2) / 57,9 (45,1-62,9)	71.3 (69.4-71.8) / 62,5 (53,4-64,0)	80.4 (75.7-84.5) / 65,8 (58,1-67,8)
Loam	55.6 (45.6-61.2} / 54,4 (44,2-60,1)	62.6 (52.1-66.7} / 59,6 (52,4-66,6)	67.2 (60.0-73.8} / 63,6 (55,2-69,9)
Gray-green clay	55.8 (38.8-65.0} / 40,4 (38,8-44,5)	61.1 (41.0-74.7) / 50,7 (41,0-57,6)	66.6 (46.4-79.2} / 61,9 (49,4-63,9)

Note: numerator- Medicago sativa, denominator- winter wheat, in parentheses - minimum and maximum possible values.

The results of long-established experiments allowed us to determine the most important factors that stipulate microorganism development in the ground. These factors are:

1. Edaphotop, as raw material for soil creation process. This factor to large extent determines physical and chemical properties of young soils. And they impact the number of microorganisms living in it. For example, undisturbed chernozem or artificially spread layer of chernozem contains 3 - 7 times as many microorganisms as loam or clay. So, biological activity level of edaphotops directly depends on their quantitative properties.
2. Size of soil particles. It stipulates air, water and nourishment conditions of soil. Soils, composed of small particles, are able to absorb a lot of water and usually contain more nutrients. These factors play the most important role in creation of microorganisms community structure on reclaimed lands.
3. Water regime of edaphotop. The water content of edaphotop depends on season and on size of particles it is composed of. If there is no enough water during long period of time microorganisms' development is suppressed. Layer of southern chernozem has the most extensive supply of moisture among all studied edaphotops, green-gray clay is in second place, after it come loam and red-brown clay. Last two edaphotops have approximately the same supplies of productive moisture.
4. The organic matter content of edaphotop. Biological peculiarities of perennial legume grasses (ability to assimilate atmospheric nitrogen, high flexibility of root system) allow them to be the pioneers of techno gene landscapes. Root systems of these crops excrete a lot of biologically active matters that stimulate microorganisms development. Besides, they live a lot of organic material, rich with nitrogen, carbon and other nutrients, in upper layer of edaphotops. Even during vegetation period of plants the disintegration of thinnest roots takes place.

The number of microorganisms in soil also depends on other factors, such as reaction of soil solution, temperature of edaphotop, air regime, composition and proportion of chemical elements, etc.

Taking into account all said above we can propose the strategy of making edaphotops more biological. It consists of three stages.

First, preliminary stage aims on careful leveling of surface of open-cast mine terrace and raising standard of arable layer by employing meliorations. The indicators of the completion of this stage are: the reclaimed field surface plane enough for using farm machines; neutral reaction of soil solution in arable layer of soil, increased number of microorganisms, germination of different plants.

Second, microbiological stage is supposed to optimize the properties of edaphotop as environment for plants. This can be achieved by using organic and mineral fertilizes. The fertilizes increase the content of easily accessible for microorganism nutrients in soil, which intensifies their development and conduces to creating more complicated structure of microbe community . The indicators of completion of this stage are: the number of microorganisms in edaphotop should be at least 50% of their number in typical zone soil; the plants should be able not only to germinate on edaphotop but also to produce significant vegetable mass.

Third stage implies improvement of soil by living organisms. It is supposed to create optimal for living organisms conditions of edaphotop in accordance with its physical and chemical properties. This stage includes the effects of all previously taken measures aimed on augmentation of soil fertility. A very important role is played by special crop rotations. It's necessary to design the most suitable crop rotation for each particular edaphotop. Proportion and sequence of crops in it should be targeted not on achieving the best possible yield but on maintaining appropriate ecological conditions, which ensure the optimum development of microbe community. The duration of this stage is interminable.

Summing it up I would like to point out that when we talk about ecological role of living organisms we should consider edaphotop as united and indissoluble system with all roots and populations of different organisms that live in it. They, in their turn, get involved into very close and very complicated interactions that result not only in formation of fertile layers in open-cast mine terraces, but also in general improvement of ecological conditions of the area.