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RESEARCH ARTICLE

Parameters of biological circulation of phytomass and nutritional elements in crop rotations

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The research shows, that an increase of phytocoenoses provided an increase of phytomass volume in the biological cycle from 63.5 to 114.3 t/ha. The yield of phytomass in a crop rotation, different in structure and set of crops, was as follows: for four-field and five-field crop rotation -63.5-86.7 t/ha, six field -89.4, seven-field -96.9, and eight-field -114.3 t/ha. The optimization of the ratio of grain, technical and fodder crops allowed us to regulate quantitative parameters of crops' phytomass, which was alienated from agrocoenosis. The yield of the main products, alienated from the field was, as follows: in four-field crop rotation -20.7 t/ha, five-field -26.6, six-field -37.8, seven field -28.4 and eight field -41.3 t/ha, which was 32.6%, 30.7%, 42.3%, 29.3% and 36.1%, respectively. The rest returned to the soil with by-products and crop remains. The total amount of nutrients (NPK) in the phytomass, involved in the circulation, was within the range for four-field crop rotation (100% of grain crops) –1,814 kg/ha, five-field (80% grain and 20% technical) –2,368 kg/hectare, six-field (66.8% of cereals, 33.2% of technical ones) -2,599 kg/ha, seven-field (57.2% of cereals and 42.8% of technical) -2,956 kg/ha, eight-field (62.5% of cereals, 25.0 % of technical, 12.5% of fodder) –3.491 kg/ha.

Keywords: Crop rotation; Phytomass of crops; Biological circulation

Introduction

With aim of developing of the scientific development of scientifically substantiated methods of increasing the biological productivity of the soil is important for defining the parameters of the phytomass cycle and nutrition elements that are part of it. Due to the goal-seeking use of soil for growing agricultural products, it is necessary to take into account the content of organic matter and nutrients in the biological mass of the harvest as well as the balance of nutrients as one of the most important factors for the development of a specific (in contrast to the virgin areas growing) cultural process of soil formation and soil fertility formation (Aksenov, 2013; Petrenko, 1998; Ryan, 2017; Tanchik, 2009). The purpose of the researches was to establish quantitative indices of the phytomass and cycling of nutrient elements in different types of crop rotation on chernozem (Tsiuk, 2013).

The turn of phiromias of field crops and its elements is one of the effective factors in the development of a specific (unlike the virgin) cultural process of soil formation and the formation of soil fertility (Panchenko, 2016; Bomba, 2001).

In the technological approach to intensification of agriculture, the environment is mostly polluted with toxic substances, soil erosion is significantly spread, the species diversity of useful flora and fauna decreases significantly, and the danger of massive damage to agricultural crops by diseases and pests increases (Kvitko, 2003). Analysis of data on this subject indicates that the strategy of comprehensive intensification of agricultural systems is vulnerable. The resource and environmental constraints of such a strategy are becoming increasingly evident (Didur, 2019). The guarantee of obtaining ecologically pure and biologically valuable products is the introduction into the structure of crop areas of field, forage and special crop rotation of perennial legumes, solving due to them the problem of protein, the transfer of nitrogen in air to vegetable protein due to bacteria that fix nitrogen, enrichment of soil without entering mineral nitrogen fertilizers, biological loosening and soil texture by the root system of plants(Butenko, 2019; Gudz, 2014; Kolisnyk, 2019). One of the key tasks of agriculture is the search for ways to optimize the water regime of the soil, the use of those agrotechnical methods that reduce the productive losses of moisture, contribute to its accumulation and preservation due to precipitation in the autumn-winter and spring periods. Important role in regulating water and nutrient regime of crop rotation and systems of basic cultivation of soil (Sylina, 2008; Saiko, 2007; Radchenko, 2018; Palamarchuk, 2018).

The effective impact of cultivation on the soil increases when the depth, methods and measures of it are carried out in a scientifically sound sequence and in close interaction with all the links of the agricultural system (Tsilurik, 2015).

Material and methods

The research was conducted in a long stationary experiment during 2015-2017 at the Panfilska research station of NSC "Institute of Agriculture of NAAS". Soil is typical, low-humus, shallow chernozem. Before conducting the test, the total content of humus in the arable layer was in the narrow range of values 3.15-3.18%, mobile phosphorus 220-250 mg, and moving potassium 80-120 mg/kg of soil. The reaction of the soil solution is slightly alkaline, the degree of saturation of the soil-absorbing complex of the bases is high (85-90%). When studying 4-8-field rotation of such crops like Winter wheat and Spring wheat, Spring barley, buckwheat, oats, corn for grain and green fodder, sugar beets, rape, sunflower, soybeans, peas (Table 1), were determined biomass of parts of field crops including their underground parts, content of basic nutrient elements and content of organic matter and nutrition elements, which alienated from the field with yield and enters the soil with post-harvest and root remains (Berdnikov, 2005; Yatsentiuk, 2010). The accounting of the main and by products of crops was carried out by weighing method during harvesting, accounting of post-harvest residues by the frame method in the triple repetition on the experimental plot, the mass of the roots by the generally accepted method in the same repetition (Armengot, 2016; Dospekhov, 1985; Caldiz, 2016; Huwe, 2002). Placement of plots was systematic according to the methodological recommendations, taking into account all trial methodology requirements by (Kyryliuk, 2013). Phenological monitoring of plants growth, development and biometric indices were determined during the main stages of organogenesis according with method of State Service for Rights Protection of Plant. The statistical processing of collected data was carried out according to dispersion method by using Statistica 6.0 and Microsoft Excel (Santín-Montanyá, 2016; Scherner, 2016; Titenko, 2010).

Results and discussion

In the system of crop rotation, when the crops in the fields interchange in time, the total phytomass depends not only on the level of the yield, but also on the set of crops in the crop rotation. According to the results of the research data were obtained for phytomass yield in crop rotation, different in structure and set of crops (Table 2.). In general, the amount of biomass in four-field crop rotation (100% saturated with grain crops) was in the range of 63.5 t/ha, in five-field crop rotation (80% of cereals and 20% of technical crops) -86.7 t/ha, of six (67% of cereals and 33% of technical ones) –89.4 t/ha, seven-field crop rotation (57% of cereals and 43% of technical crops) –96.9 t/ha, eight-field rotation (62.5% of cereals, 25% of technical and 12.5 fodder crops) – 114.3 t / ha. From the obtained phytomass from the field, 32.6%, 30.7, 42.3, 29.3 and 36.1% were alienated, respectively, the rest returned to the soil with plant remains.

Analyzing the parameters of the alienation of a part of the phytomass from its total circulation, separately in the crop rotation, it should be noted that in eight-field crop rotation (var. 9) 62.5% saturated cereal spike cultures (Winter wheat and yarrow, Winter rye, barley and oats), 25 % of technical (soy and sunflower) and 12.5% of fodder crops (corn on green feed), the amount of phytomass, which alienated from the circulation, amounted to 41.3 t/ha or 36.1%. In six-field crop rotation (var. 6) where the proportion of grain crops was 67%, and technical crops was 33%, of which 16.7% occupy the sugar beets, the highest (42.3%) relative index of alienation of phytomass from the general circulation was determined. That is, the introduction of sugar beet crop rotation, namely the widespread ratio of this crop, between the main (root crop) and the by-product (hybrid) production and the low incidence of biomass with root residues, has a significant influence on the parameters of the cycling of phytomass crop rotation in general.

Analyzing the four-field crop rotation on 100% saturated crops and five-way crop rotation, saturated with 80% and 20% technical crops (sunflower), similar in composition of grain crops, it should be noted that the expansion of the set of crops and their share in crop rotation has provided growth rates the total circulation of phytomass at 23.2 t/ha, and the reduction of the part of alienation of phytomass by almost 2%, compared with 4-crop rotation. Based on the obtained data on the release of dry matter of phytomass and chemical composition of plants parameters of biological and economic removal of nutrient elements of crops in different crop rotation are determined (Table 3). In four-field crop rotation for 100% saturation with grain crops, the total amount of nutrients involved in biological circle was 1814 kg/ha (var. 3). With a yield of above-ground phytomass, 44% of the total amount of nutrients was alienated, and 56% remained in the soil, respectively. The circulation of field crops phytomass and nutritional elements is one of the efficient factors of development of a specific (as opposed to virgin) cultural process of soil formation and soil fertility formation.

Table 1. Scheme of stationary experiment with investigation of crop rotation in terms of left-bank Forest-steppe– Panfylska research station of NSC "Institute of Agriculture NAAS".

№ of var.	Interchanging and fertilization of crops in crop rotation								Fertilization on 1 ha of arable land			
	I	II	III	IV	V	VI	VII	VIII	Organic manure, t	Mineral fertilizes, kg of active substance		
										N	P	K
3	**Pea** $N_0P_{30}K_{40}$	**Winter wheat** $N_{60}P_{60}K_{60}$	**corn for grain** $N_{60}P_{60}K_{60}$	**Spring rapeseed** $N_{60}P_{60}K_{60}$	-				beaten production	45	55	55
5	**Pea** $N_0P_{30}K_{40}$	**Winter wheat** $N_{60}P_{60}K_{60}$	**sunflower** $N_{90}P_{60}K_{90}$	**Spring barley** $N_{60}P_{60}K_{60}$	**Corn for grain** $N_{60}P_{60}K_{60}$				-//-	54	56	62
6	**Soybeans** $N_0P_{30}K_{40}$	**Winter wheat** $N_{60}P_{60}K_{60}$	**Sugar beet** $N_{100}P_{100}K_{100}$	**Spring barley** $N_{60}P_{60}K_{60}$	**Corn for grain** $N_{60}P_{60}K_{60}$	**Buckwheat** $N_{40}P_{40}K_{40}$			-//-	53	60	60
8	**Winter rapeseed** $N_{60}P_{60}K_{80}$	**Winter wheat** $N_{60}P_{60}K_{60}$	**Sunflower** $N_{90}P_{60}K_{90}$	**Spring wheat** $N_{60}P_{60}K_{60}$	**Soybeans** $N_0P_{30}K_{40}$	**Winter wheat** $N_{60}P_{60}K_{60}$	**Spring barley** $N_{60}P_{60}K_{60}$		-//-	57	57	64
9	**corn for Green forage** $N_{60}P_{60}K_{60}$	**Winter wheat** $N_{60}P_{60}K_{60}$	**Sunflower** $N_{90}P_{60}K_{90}$	**Spring wheat** $N_{60}P_{60}K_{60}$	**Soybeans** $N_0P_{30}K_{40}$	**Winter rye** $N_{60}P_{60}K_{60}$	**Oat** $N_{60}P_{60}K_{60}$	**Spring barley** $N_{60}P_{60}K_{60}$	-//-	56	58	64

Note. * –It will be making of beaten manure in all predecessor crops.

In the case of growing legumes with cereals, the indicated effect of legumes on the soil is completely eliminated. Bean-cereal mixtures favorably influence the soil fertility, increasing the accumulation of organic matter in it, improving its structure, permeability, aeration (Prymak, 2017). At the same time, the turf of cereal-bean grass mixtures promotes the use of not only droplets of moisture, but also water vapor (sucking it as a sponge) (Provorov, 2013).

According to the results of the study, it was found that an increase in the species diversity of phytocoenoses provided an increase in the phytomass content of crops in the biological cycle from 63.5 to 114.3 t/ha. The yield of phytomass in crop rotation, which differed in structure and crop set, was: for four-wheeled and five-wheeled crop rotation -63.5 ... 86.7 t/ha, six-crop -89.4 t/ha, semi-fodder - 96.9 t/ha, octopus - 114.3 t/ha. Optimization of the ratio of crop rotation of grains, technical and forage crops allowed to regulate the quantitative parameters of phytomass of agricultural crops alienated from agrocenosis.

It was investigated that the yield of the main products from the field was alienated in four-wheeled crop rotation -20.7 t/ha, fivefold -26.6 t/ha, six-tern -37.8 t/ha, semifurnal -28.4 t/ha and octopus -41.3 t/ha, which in relative terms was 32.6%, 30.7%, 42.3%, 29.3 and 36.1%, respectively, the rest returned to the soil with by-products and poplars.

The total amount of nutrients (NPK) in the phytomass, which was involved in the colloid, was within the limits for four-wheeled crop rotation (100% of grain crops) -1814 kg/ha, five-grain (80% of cereals and 20% of technical) -2368 kg/hectare, six-(66.8% of grain, 33.2% of technical) -2599 kg / ha, 7-field crop rotation (57.2% of cereals and 42.8% of technical) -2956 kg/ha, 8-field crop rotation (62.5% of cereals, 25.0% of technical, 12.5% of feed) -3491 kg/ha. It was established that, depending on the structure of crop rotation, the yield of phytomass from the field was alienated from 1020 to 1738 kg/ha NPK.

Increasing the rotation of crop rotation to 5 fields (80% of cereals and 20% of technical), an increase in the total number of nutrition elements in the circle of 30%, compared to four-field crop rotation, to 2368 kg/ha (var 5). It was also found that in five-field crop rotation with 80% saturation of cereals and 20% saturation of technical crops, the average share of NPK in plant remains was 57% in the experiment.

Table 2. Phytomass exchange in agriculture crops rotations system, (the average, 2015-2017).

Variant	Structure of crop rotations, %											Average crop rotation fertilizers doze				Crops phytomass (dry substance)							
	grains						Sugar beet	soybean	sunflower	rapeseed	corn for green forage	organic	N	P	K	Totally, t/ha	including							
	totally	including											kg/ha of active substance				Alienated from field		with beaten production		Input in soil after-harvesting crop remnants		Including with the roots remnants	
		winter/ spring wheat	corn	buckwheat	pea	barley/ oat											t/ha	%	t/ha	%	t/ha	%	t/ha	%
4-field crop rotation																								
3	100,0	25/-	25	-	25	25/-	-	-	-	-		Byproducts* of the precursor	45	55	55	63,5	20,7	32,6	27,2	42,8	15,6	24,6	10,1	64,7
5-field crop rotation																								
5	80,0	20/-	20	-	20	20/-	-	-	20	-		-//-	54	56	62	86,7	26,6	30,7	40,2	46,4	19,9	23,0	11,6	58,3
6-field crop rotation																								
6	66,8	16,7/-	16,7	16,7	-	16,7/-	16,7	16,7	-	-		-//-	53	60	60	89,4	37,8	42,3	33,2	37,1	18,4	20,6	11,0	59,8
7-field crop rotation																								
8	57,2	28,6/14,3	-	-	-	14,3/-	-	14,3	14,3	14,3		-//-	57	57	64	96,9	28,4	29,3	43,4	44,8	25,1	25,9	14,3	57,0
8-field crop rotation																								
9	62,5	12,5/12,5	-	-	-	12,5/ 12,5	-	12,5	12,5	-	12,5	-//-	56	58	61	114,3	41,3	36,1	43,3	37,9	29,7	26,0	17,6	59,3

Note. * – it is supposed to introduce for all crops of byproducts of the precursor

Table 3. Exchange of basic nutrition elements in sowing of agriculture crops on chernozem soils, (average by 2015-2017).

Variant	Структура сівозмін, %							Average crop rotation fertilizers doze				Content of basic nutrient elements in biomass									
	Cereals	legumes		Weeding crops			Forage crops		N	P	K	Amount of nutrient elements , kg	including			Alienated with harvest		Returns to the soil with vegetable remains totally		including, kg	
		pea	soybeans	Corn for grain	sugar beet	sunflower /rapeseed	corn for green forage	organic	kg/ha of active substance				N	P	K	totally, kg/ha	%	kg	%	N	P	K
4-field crop rotation																					
3	100,0	25,0	-	25	-	-	-	Byproducts* of the precursor	45	55	55	1814	934	289	591	792	44	1022	56	448	123	452
5-field crop rotation																					
5	80,0	20,0	-	20	-	20/-	-	-//-	54	56	62	2368	1208	381	779	1020	43	1349	57	586	165	597
6-field crop rotation																					
6	66,8	-	16,7	16,7	16,7	-	-	-//-	53	60	60	2599	1277	354	968	1186	46	1413	54	560	148	705
7-field crop rotation																					
8	57,2	-	14,3	-	-	14,3/14,3	-	-//-	57	57	64	2956	1408	458	1090	1335	45	1621	55	571	176	876
8-field crop rotation																					
9	62,5	-	12,5	-	-	12,5/-	12,5	-//-	56	58	61	3491	1594	497	1400	1738	50	1753	50	632	174	947

Note. * – it is supposed to introduce for all crops of byproducts of the precursor

In the six-field crop rotation (var. 6), the total NPK in biomass was 2599 kg/ha, the yield of 1186 kg/ha (46%) was alienated, and 1413 kg/ha or 54% was returned to the soil with vegetable residues, including N -560, P-148 and K-705 kg/ha. In the seven-field crop rotation (var. 8), the lowest part of grain crops (57%) was the alienation of nutrients with a yield of basic products of 1335 kg/ha, while the level of return to the soil with vegetable remains was 1621 kg/ha or 55%. The introduction of corn on the green fodder (var 9) into the structure of eight-field crop rotation increased the parameters of the removal of NPK with a yield of the main products to 1738 kg/ha and a decrease in the level of supply of nutrients to the soil with plant remains to 1753 kg, or 50% of the total cycle of nutrition elements. With the increase in the structure of crop rotation of the proportion of such crops as corn and sunflower, the total amount of nutrients in phytomass increased, while for the introduction of grain crop rotation of sugar beet and maize into green fodder, the proportion of the phytomass cycle that was alienated from the field grew.

Conclusion

It is established that in the system of diversified crop rotation, the total phytomass of plants, as well as the amount of nutrients that are part of it, is determined not only by the level of productivity of the main and by-products of crops, but also largely by the structure and set of crops in the crop rotation. Given the need to evaluate the crop rotation not only in terms of output but also in terms of the quantity and quality of plant residues entering the soil as a source of compensation for humus losses, among the studied options, priority is given to crop rotation in 80% of saturated crops (incl. 20% corn for grain) and 20% technical (sunflower): the yield of biomass as well as its amount returning to the soil with plant residues, including those with roots, was 57%, and the share that alienates the smallest among the studied crop rotations is 43%.

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