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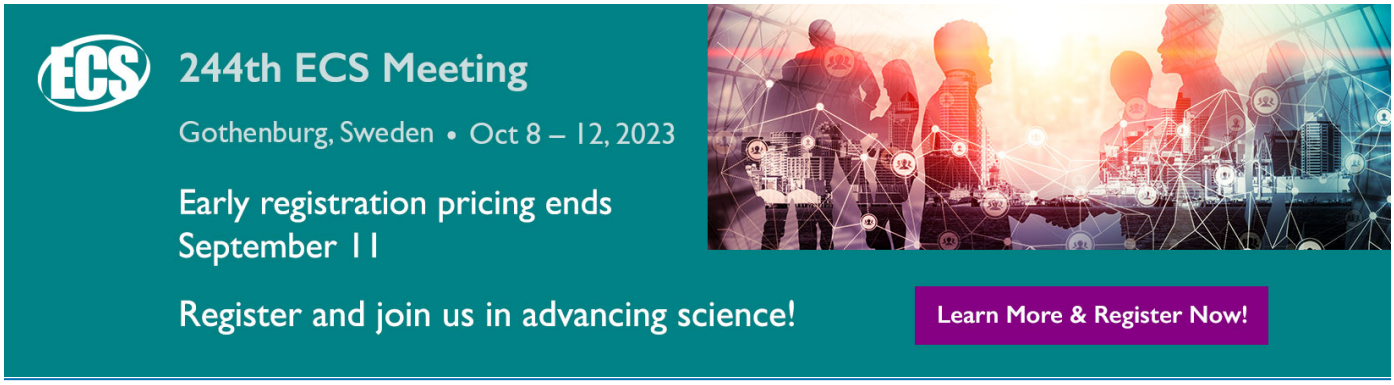

Changes in agrochemical indicators in an agricultural landscape with sod-podzolic soils against the background of the use of non-traditional fertilizers

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Abstract. The results of changes in agrochemical indicators in an agricultural landscape with sod-podzolic soils against the background of the use of non-traditional fertilizers in the Yaroslavl region are presented. A consequence of the intensive development of poultry farming and greenhouse farming in the region is not only an increase in the volume of basic products, but also the accumulation of production waste, such as poultry manure in poultry farming and used mats of the greenhouse economy. Both types of waste are environmentally hazardous and require special care when disposing of them. One of the options for solving the problem may be the processing of waste into a granular organic-mineral substrate. Evaluation of the effectiveness of the use of unconventional fertilizers was carried out in a 3-factor stationary field experiment while simultaneously studying the systems of basic soil cultivation and plant protection. The studies have shown that the developed organomineral fertilizer, created from waste chicken manure and mineral mats, does not have a negative effect on the agrochemical indicators of soil fertility and can be recommended for production.

1. Introduction

The agrochemical properties of the soil determine its nutritional regimes. The special role of organic matter in soil fertility is explained by the following: the causal relationship between organic matter and the emergence of soil, the global impact of organic matter on the complex of agronomic properties of the soil, feedback between agrotechnical methods and the content of organic matter in arable soil, the impossibility of replacing the role of organic matter with farming methods [1,2].

It is possible to ensure a deficit-free balance of humus on loamy and clayey soddy-podzolic soils by incorporating about 8-9 t / ha of manure into crop rotation areas with the obligatory cultivation of perennial grasses [3,4]. For faster enrichment of soddy-podzolic soils with organic matter, it is advisable to apply organic fertilizers with a lower rate of mineralization. The decisive role in this case can be assigned to poultry waste. Poultry manure as an organic fertilizer is especially valuable both in terms of the content of nutrients and their availability for cultivated crops [5].

The content of nutrients in the soil has a direct direct effect on the growth and development of plants. The availability of mobile forms of phosphorus is one of the defining signs of high fertility and cultural condition of the soil [6,7,8]. As the content of mobile phosphates in the soil and the degree of their mobility increase to a certain limit, the yield of crops increases and their resistance to unfavorable conditions increases [9,10]. Sowing of agricultural crops in favorable conditions of

nitrogen and phosphorus nutrition satisfy their need for potassium largely due to its mobilization from soil reserves [11]. An increase in the level of potassium consumption by plants under the influence of potash fertilization has a weak effect on the productivity of crops in field crop rotation. The residual amount of potassium is fixed in the root layer of the soil in exchangeable and non-exchangeable forms available to plants, which predetermines its use by crops in crop rotation [12].

In different soils, the soil solution has a specific reaction. In addition to the composition of soil cations, the pH of the soil solution is influenced by carbon dioxide, the presence of acidic or alkaline products of microbial metabolism, etc. The high concentration of hydrogen ions in the soil solution strongly inhibits the vital activity of microorganisms that carry out nitrogen mineralization and nitrogen fixation [13].

With the intensive development of greenhouse production and poultry enterprises in the Yaroslavl region, the issue of waste disposal is a priority task. Therefore, the development of a method for disinfecting a greenhouse substrate, enriching it with nutrients through the use of poultry manure and obtaining an organomineral substrate as fertilizer for field crops is quite relevant for agricultural producers and ecology, sod-podzolic gley soils, which occupy a significant part of the soil cover of the region.

2. Materials and Methods

Agrochemical analysis of the influence of soil cultivation systems and the aftereffect of the organic-mineral substrate on soil fertility was carried out in a 3-factor stationary field experiment, laid down on the experimental field of the Federal State Budgetary Educational Institution of Higher Education of the Yaroslavl State Agricultural Academy (Bekrenevo village, Yaroslavl region).

The work was carried out in 2019 on sod-podzolic gley medium loamy soil in the sowing of spring rape (Virazh variety). To accomplish this goal, we used a three-factor stationary field experiment, laid down on the experimental field of the Yaroslavl State Agricultural Academy.

Scheme of a field stationary three-factor (2 × 6 × 2) experiment:

Factor A. System of basic tillage, «O»: 1) Plowing, «O_1»; 2) Surface tillage, «O_2».

Factor B. Fertilizer system, «U»: 1) Without fertilizers, «U_1»; 2) Used mineral wool IZOVOL AGRO UNIVERSAL, «U_2»; 3) Organo-mineral substrate, «U_3»; 4) Disinfected chicken droppings, «U_4»; 5) Organo-mineral substrate + NPK, «U_5»; 6) NPK, «U_6».

Factor C. Plant protection system, «G»: 1) Without herbicide, «G_1»; 2) With herbicide, «G_2».

Among the forms of mineral fertilizers used were azofoska, urea and potassium chloride. The rate of mineral fertilizers was $N_{105}P_{15}K_{25}$.

For the research, we used vegetation mats obtained from LLC «Greenhouse Plant Yaroslavsky». Vegetation mats are made by IZOVOL AGRO UNIVERSAL from environmentally friendly mineral wool based on basalt rocks. Approximate chemical composition of raw materials: SiO_2 45-65%; Al_2O_3 10-20%; CaO 5-15%; MgO 5-10%; Fe_2O_3 + FeO 10-15%; Na_2O + K_2O 1-3%. Poultry (chicken) droppings were obtained from a poultry farm.

Chicken droppings, spent growing mats and organic-mineral substrate were introduced in the spring of 2017 for the main treatment. Chicken droppings were incorporated at a rate of 41 c/ha, which is $N_{80}P_{65}K_{40}$ in terms of the active ingredient. The application rate of mineral wool was 2.1 c/ha.

In the experiment, the herbicide Shkiper, WS was used at the rate of 0.3 l/ha in the phase 3-4 of a true rape leaf.

The content of organic matter in the soil was determined by the method of I.V. Tyurin in the modification of TsINAO. The content of mobile phosphorus and exchangeable potassium was determined by the Kirsanov method in the modification of TsINAO. Exchangeable acidity was determined by potentiometric method. Hydrolytic acidity was determined by the Kappen-Gilkovits method. The selection of soil samples to determine the content of agrochemical parameters was carried out in all variants of the experiment on two layers of the arable horizon at the end of the growing season of spring rape. In a solution of ash obtained by wet ashing of plant samples in sulfuric acid with hydrogen peroxide, the content of nitrogen (using a Kjeldahl microapparatus), phosphorus

(using a vanadomolybdate method), and potassium (using a flame photometer) was determined. The yield of spring rapeseed was determined by the continuous plotting method with conversion to absolutely pure products. For statistical processing of the experimental data, the DISANT program was used.

3. Results

An analytical analysis of soil samples made it possible to highlight the role of the studied factors in changing the agrochemical indicators of soil fertility (table 1).

Table 1. Effect of different tillage systems, fertilizers and herbicides on agrochemical soil properties.

Variant	Agrochemical indicators of soil fertility				
	organic matter content, %	P_2O_5 content, mg / kg	K_2O content, mg / kg	hydrolytic acidity, meq / 100 g of soil	pH_{KCl}
Factor A. System of basic tillage, «O»					
Plowing, «O_1»	3.56	229.91	129.86	1.77	5.47
Surface tillage, «O_2»	3.53	231.87	127.12	1.72	5.55
LSD_{05}	$F_f<F_{05}$	$F_f<F_{05}$	$F_f<F_{05}$	$F_f<F_{05}$	$F_f<F_{05}$
Factor B. Fertilizer system, «U»					
Without fertilizers, «U_1»	3.40	206.77	122.68	1.79	5.47
Used mineral wool IZOVOL AGRO UNIVERSAL, «U_2»	3.53	216.83	126.03	1.76	5.45
Organo-mineral substrate, «U_3»	3.74	227.00	124.00	1.83	5.34
Disinfected chicken droppings, «U_4»	3.55	242.04	129.73	1.69	5.43
Organo-mineral substrate + NPK, «U_5»	3.51	253.02	139.17	1.50	5.97
NPK, «U_6»	3.54	239.67	129.33	1.89	5.40
LSD_{05}	$F_Φ<F_{05}$	19.64	5.81	0.24	0.17
Factor C. Plant protection system, «G»					
Without herbicide, «G_1»	3.49	224.58	127.51	1.72	5.51
With herbicide, «G_2»	3.60	237.19	129.47	1.76	5.51
LSD_{05}	$F_f<F_{05}$	8.87	$F_Φ<F_{05}$	$F_f<F_{05}$	$F_f<F_{05}$

On average for the factors, the use of the surface tillage system did not cause any significant changes in the content of organic matter. A similar trend was observed in relation to other studied soil agrochemical indicators - the content of mobile phosphorus and exchangeable potassium, hydrolytic and exchangeable acidity. In general, all indicators were at the same level.

On average, for the systems of treatment and protection of plants, the use of the studied fertilizer systems did not reveal significant changes in the content of organic matter with the highest values for the background «Organo-mineral substrate» - 3.74%. The use of fertilizers on the options «Disinfected chicken manure», «Organo-mineral substrate + NPK» and «NPK» contributed to a statistically significant increase in the content of mobile phosphorus by 20.23, 35.23 and 32.9 mg / kg, respectively. A similar dynamics was noted with respect to the content of exchangeable potassium against the same background of fertilizers. The use of an organo-mineral substrate and mineral

fertilizers at a dose of $N_{105}P_{15}K_{25}$ provided a significant decrease in hydrolytic acidity by 0.29 mg-eq / 100 g of soil. In the same variant, a maximum pH value of 5.97 was observed.

The use of the herbicide did not have a significant effect on the studied agrochemical properties of the arable horizon, with the exception of a significant increase in the content of mobile phosphorus from 224.58 to 237.19 mg / kg.

As you know, the size and quality of the crop is largely determined by the nutrient regime of the soil, however, under the conditions of our experience, the phytosanitary state of crops and soil turned out to be the limiting factor in the productivity of sowing.

The results of the correlation-regression analysis indicate the presence of an average in density interaction between the productivity of spring rapeseed and exchangeable acidity of the soil (r = -0.63); weak dependences were noted with the rest of the agrochemical parameters. The level of green mass yield was determined by all studied factors (table 2).

Table 2. Effect of different systems of basic tillage, fertilization and plant protection on the yield of green mass of spring rape.

Variant	Productivity, t / ha
Factor A. System of basic tillage, «O»	
Plowing, «O_1»	14.29
Surface tillage, «O_2»	12.38
LSD_{05}	1.31
Factor B. Fertilizer system, «U»	
Without fertilizers, «U_1»	9.06
Used mineral wool IZOVOL AGRO UNIVERSAL, «U_2»	9.92
Organo-mineral substrate, «U_3»	12.44
Disinfected chicken droppings, «U_4»	13.12
Organo-mineral substrate + NPK, «U_5»	18.40
NPK, «U_6»	17.07
LSD_{05}	1.36
Factor C. Plant protection system, «G»	
Without herbicide, «G_1»	12.28
With herbicide, «G_2»	14.39
LSD_{05}	0.78

On average in terms of factors the use of a surface tillage system caused a statistically significant decrease in the yield of spring rape by 1.91 t / ha. On average for the systems of basic soil cultivation and plant protection fertilization according to the backgrounds «Used mineral wool IZOVOL AGRO UNIVERSAL», «Organo-mineral substrate» - 3.74%. The use of fertilizers on the options «Disinfected chicken manure», «Organo-mineral substrate + NPK» and «NPK» led to a significant increase in yield at maximum values on the option «Organo-mineral substrate + NPK» - 184.0 c / ha. The use of the herbicide in the sowing of rapeseed led to a significant increase in the yield of green mass by 2.1 t / ha.

One of the important aspects in assessing the effect of agricultural practices is their effect on the chemical composition of plants, which determines the quality of the products obtained. The data obtained in the third year of the experiment on the study of the chemical composition of the dry mass of rapeseed plants made it possible to calculate the content of the considered mineral elements in the composition of a unit of the obtained product and showed its variability depending on the conditions of using mineral wool, fertilizers and the system of basic tillage (table 3).

According to the background of surface tillage there was a tendency to an increase in the content of nitrogen and phosphorus per unit of yield on average for the systems of fertilization and plant protection. The use of chicken manure and mineral wool both separately and as part of an organomineral substrate did not reduce the level of these nutrients in the composition of plants. Their

highest content in the harvest was noted against the background of the annual use of mineral fertilizers. The amount of potassium in the green mass ranged from 0.53 to 0.76% and was not determined by the soil cultivation system. The aftereffect of chicken droppings was manifested in an increase in the content of this nutrient in comparison with the control. With the addition of mineral wool to chicken manure, a slight decrease in the content of potassium in the composition of a unit of green mass was noted. The use of the herbicide in the plant protection system somewhat reduced the content of nutrients in the products.

Table 3. Effect of various systems of basic tillage, fertilizers and plant protection on the content of nutrients in green mass and their removal by the harvest of spring rape.

Variant	The content of nutrients in the green mass of spring rape, %			Removal of nutrients by the harvest of spring rape, kg / ha		
	N	P	K	N	P	K
Factor A. System of basic tillage, «O»						
Plowing, «O_1»	0.39	0.18	0.63	57.14	25.63	92.47
Surface tillage, «O_2»	0.42	0.19	0.62	53.40	24.47	76.92
Factor B. Fertilizer system, «U»						
Without fertilizers, «U_1»	0.36	0.18	0.57	32.35	16.05	52.00
Used mineral wool IZOVOL AGRO UNIVERSAL, «U_2»	0.37	0.17	0.59	36.37	17.17	58.35
Organo-mineral substrate, «U_3»	0.37	0.18	0.58	46.35	22.42	72.80
Disinfected chicken droppings, «U_4»	0.40	0.19	0.67	52.52	24.57	88.07
Organo-mineral substrate + NPK, «U_5»	0.46	0.19	0.69	83.45	34.45	127.40
NPK, «U_6»	0.47	0.20	0.66	80.55	35.65	112.03
Factor C. Plant protection system, «G»						
Without herbicide, «G_1»	0.41	0.19	0.64	51.65	23.54	80.37
With herbicide, «G_2»	0.39	0.18	0.61	58.88	26.57	89.85

The NPK removal by the crop is widely used when calculating fertilizer doses using balance methods; the research results confirm the variability of its values for the same soil depending on the growing conditions. Differences in the size of the crop and the content of mineral elements in its composition according to different variants of the experiment were reflected in the amount of nitrogen, phosphorus and potassium removal by the crop. The highest removal of nutrients was noted against the background of moldboard tillage on average for fertilization and plant protection systems.

The introduction of poultry manure together with mineral fertilizers contributed to a significant increase in nitrogen removal. On the variant with the use of one poultry manure the nitrogen removal increased by 20.2 kg / ha. Embedding of mineral wool did not reduce this indicator in comparison with the control. The maximum nitrogen removal was observed in the variants of using mineral fertilizers against the background of an organo-mineral substrate. The influence of mineral wool on phosphorus removal is insignificant. A noticeable positive aftereffect of chicken droppings and organo-mineral substrate. An unambiguous effect of the organo-mineral substrate on the assimilation of phosphorus with the use of mineral fertilizers was not revealed. The greatest removal of potassium was observed in the variants of the annual application of mineral fertilizers, and it should be noted at the same time the positive effect of the previously introduced organo-mineral substrate based on chicken manure.

Against the background of the use of the herbicide the removal of nutrients is higher in comparison with options without their use.

4. Discussion

Without taking into account the potential and effective soil fertility it is not possible to effectively use fertilizers, contributing to an increase in soil fertility and obtaining a high yield. Determination of nutrients in the soil gives an idea of heir reserves and allows you to calculate the amount of nutrients needed for the growth and development of plants. In this regard, before setting up the experiment mixed soil samples were taken to study the agrochemical characteristics of the soil. As a result of the studies it was found that the soil of the arable horizon contained: organic matter - 2.86%, exchangeable potassium - 143 mg / kg, readily available phosphorus - 286.1 mg / kg soil, hydrolytic acidity - 2.07 mg-eq / 100 g of soil, pH_{KCl} - 5.5. According to the content of nutrients. it belongs to the medium-cultivated and suitable for the cultivation of field crops.

As a result of three years of agricultural use changes in the chemical and some physicochemical properties of the soil were observed on average over the experience in comparison with the values hat were determined before the establishment of the experiment. An increase in organic matter content of 0.68% was observed in the arable layer, which may be associated with the use of different fertilization systems.

The content of mobile forms of phosphorus by the third year of the action of factors gradually decreased. The phosphorus content decreased (by 55.21 mg / kg of soil on average), which can be explained by a higher removal of crops with a crop, and a decrease in the readily available form due to its transition to inaccessible forms.

The content of exchangeable potassium in the soil after three years, despite the use of fertilizers, did not increase, but decreased by 14.51 mg / kg of soil on average. This can be attributed to its consolidation with soil. Studies have established that exchangeable potassium has different bond strengths with the soil-absorbing complex of sod-podzolic soil and different degrees of mobility. Consequently, they have a significant reserve for supplying plants with potassium. If it is insufficiently supplied to the soil with fertilizers, crop rotation crops mobilize potassium from the exchangeable and then non-exchangeable forms, as a result of which the plants do not experience a lack of potassium [15].

No changes were revealed in the indicators of exchangeable acidity (pH_{KCl}) in the whole experimental area. The root-inhabited layer of sod-podzolic gleyic soil was characterized by a slightly acidic reaction of the soil solution, which may be due to the moderate application of mineral fertilizers.

During the experiment, hydrolytic acidity decreased from 2.07 to 1.74 mg-eq / 100 g of soil, which is explained by short-term excessive moisture, which affects the process of leaching of the arable layer.

5. Conclusion

Thus, the incorporation into the soddy-podzolic soil of an organic-mineral substrate, consisting of disinfected chicken manure and waste vegetation mats, improves agrochemical fertility and ensures an increase in the yield of spring rape, both with independent use and when applied together with a full norm of mineral fertilizers. The use of the studied fertilization systems does not lead to a decrease in the content of the main nutrients in the composition of spring rape plants. The removal of nitrogen, phosphorus, potassium is determined by their content in the unit of yield and the value of the yield. On average, the assimilation of mineral elements is higher against the background of moldboard tillage with the use of a herbicide.

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