Artículo de investigación

The effectiveness of chemicals in the cultivation of winter rye on soil contaminated by radiation

Эффективность средств химизации при возделывании озимой ржи на радиоактивно загрязненной почве

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Abstract

In a long-term stationary field experiment of the Novozybkovsky State Agricultural Experimental Station of the All-Russian Research Institute of Lupine on sod-podzolic sandy soil contaminated with ^{137}Cs 526-666 kBq / m^2. the effectiveness of chemical means for cultivating winter rye Pukhovchanka was studied. It was established that the use of organic-mineral (aftereffect of manure 40 t / ha + $N_{70}P_{30}K_{60}$) and mineral $N_{140}P_{60}K_{120}$ fertilizer systems in combination with chemical plant protection products and a humistim biological product can increase the yield of winter rye grain by 4.1 - 4.4 times compared to control. The complex use of fertilizers. pesticides and humistima contributed to a significant increase in the physical and baking indicators of grain quality relative to control. The use of fertilizer. both separately and in combination with chemical plant protection products and humistim. reduced the accumulation of ^{137}Cs in winter rye grains by 1.95 - 5.60 times compared with the control. which ensured the production of normatively clean products in technologically polluted areas. The greatest

Аннотация

В длительном стационарном полевом опыте Новозыбковской государственной сельскохозяйственной опытной станции ВНИИ люпина на дерново-подзолистой песчаной почве загрязненной ^{137}Cs 526-666 кБк/$м^2$, изучена эффективность средств химизации при возделывании озимой ржи сорта Пуховчанка. Установлено, что применение органоминеральной (последействие навоза 40 т/га + $N_{70}P_{30}K_{60}$) и минеральной $N_{140}P_{60}K_{120}$ системы удобрения в комплексе с химическими средствами защиты растений и биопрепаратом гумистим позволяет повысить урожайность зерна озимой ржи, по сравнению с контролем, в 4,1 – 4,4 раза. Комплексное использование удобрения, пестицидов и гумистима способствовало достоверному повышению физических и хлебопекарных показателей качества зерна, относительно контроля. Применение удобрения, как отдельно, так и в сочетании с химическими средствами защиты растений и гумистимом, снижало накопление ^{137}Cs в зерне озимой ржи, по

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energy and economic efficiency was noted in the organic-mineral fertilizer system in combination with pesticides and a humistim biological product. where the profitability level of winter rye grain production was 92.6%.

Key words: Winter rye. fertilizers. pesticides. humistim. productivity. quality. ^{137}Cs. efficiency.

сравнению с контролем, в 1,95 – 5,60 раза, что обеспечило производство нормативно чистой продукции на техногенно загрязненной территории. Наибольшая энергетическая и экономическая эффективность отмечена по органоминеральной системе удобрения в комплексе с пестицидами и биопрепаратом гумистим, где уровень рентабельности производства зерна озимой ржи составил 92,6%.

Ключевые слова: озимая рожь, удобрения, пестициды, гумистим, урожайность, качество, ^{137}Cs, эффективность.

Introduction

Winter rye is one of the most widespread and most important grain crops that affect human vital activity and significantly determine the food security of the country (Gamzikov. Ankudovich. 2018; Belous et al. 1987). It surpasses other winter crops in winter hardiness and adaptability. it is also able to form a crop on various types of soils. including sandy ones; the share of sandy soils in the European part of the Non-Black Earth Zone of Russia is more than 5 million ha or about 22% of the total arable land (Belous and Kharkevich. 1999; Malyavko et al. 2000; Sysuev. 2012).

With extensive radioactive contamination of soils in the south-west of the Central region of Russia. characterized by a low level of natural fertility. the priority task facing agricultural science is the development and implementation of winter rye cultivation technologies. based on the integrated use of protective agricultural methods. ensuring normatively clean products (Bogomolova et al. 2018; Pilipenko.

Dneprovskaya. 2012; Kosyanchuk et al. 2004). The agroecological. energy and economic assessment of the effectiveness of the integrated use of chemicals in the conditions of radioactive contamination of agrocenoses is relevant in a market economy. with constant disparity in prices for energy. chemicals. seeds and planting stock (Belous et al. 2017; Pakshina et al. 2017; Belous et al. 2016).

The purpose of the research is to study the effect of various fertilizer systems. plant protection chemicals. and the humistim biological product on the efficiency of growing winter rye on radioactively contaminated sod-podzolic sandy soil in the south-west of the Central region of Russia.

Materials and methods

The studies were carried out in 2003-2013 in the stationary field experiment of the Novozybkovsky State Agricultural Experimental Station of the All-Russian Research Institute of Lupine established in 1993. Winter rye of the Pukhovchanka variety was cultivated in a four-field fruit crop rotation: potatoes - oats - lupine for green mass - winter rye. The soil of the experimental plot is sod-podzolic. sandy and was characterized by the following indicators: organic matter content 2.4–2.5%. pH_{KCL} 6.7–6.9. mobile phosphorus and exchange potassium content 385–413 and 69–96 mg / kg respectively. The density of ^{137}Cs soil contamination ranged from 526–666 kBq / m^2.

The experience was laid in four repetitions. the size of the accounting plot is 45 m^2. The allocation of plots is systematic. Winter rye cultivation agricultural technology generally accepted for the zone.

The experimental design included the following options: control (without fertilizers); aftereffect of manure 80 t / ha; aftereffect of manure 40 t / ha + + $N_{70}P_{30}K_{60}$; $N_{70}P_{30}K_{60}$; $N_{140}P_{60}K_{120}$; $N_{210}P_{90}K_{180}$; aftereffect of manure 40 t / ha + $N_{70}P_{30}K_{60}$ + pesticides; N70P30K60 + pesticides; N140P60K120 + pesticides; N210P90K180 + pesticides; aftereffect of manure 40 t / ha + $N_{70}P_{30}K_{60}$ + pesticides + humistim; $N_{70}P_{30}K_{60}$ + pesticides + humistim; $N_{140}P_{60}K_{120}$ + pesticides + humistim; $N_{210}P_{90}K_{180}$ + pesticides + humistim.

Cattle manure. containing on average (%): moisture - 77.2. nitrogen - 0.53. phosphorus - 0.25. potassium - 0.57 were introduced under the first crop rotation crop (potato). Ammonium nitrate. double granular superphosphate. potassium chloride were used as mineral fertilizers. Phosphorus fertilizer was introduced in the fall in pre-sowing cultivation of the soil. Nitrogen and potassium fertilizers were applied fractionally: $N_{60}K_{60}$ ($N_{30}K_{30}$ before sowing in the fall + $N_{30}K_{30}$ in spring when the growing season resumes). $N_{140}K_{120}$ ($N_{30}K_{30}$ before sowing + $N_{70}K_{90}$ spring renewal of vegetation + N_{40} phase of entry into the tube); $N_{210}K_{180}$ ($N_{30}K_{30}$ before sowing + $N_{90}K_{150}$ spring resumption of vegetation + N_{90} phase of exit into the tube).

We used chemical plant protection products against diseases and pests: foundationazole 50% wp(wettable powder) - 0.6 kg / ha in the fall during the tillering phase; camposan M - 4 l / ha in the exit phase into the tube; bayleton 25% wp - 0.6 kg / ha at the start of heading phase. decis 25% wp - 0.3 l / ha in the flowering phase.

Winter rye crops were treated with a humistim biopreparation in the spring in the phase of complete tillering — the beginning of the release into the tube at the rate of 6 l / ha. The humistim biopreparation manufactured by Ginseng Specialized Agricultural Enterprise LLC contains all the dissolved vermicompost components: humins. fulvic acids. natural. phytoharmones. vitamins. macro- and microelements in the form of bioavailable organic compounds. The fungicidal and bactericidal properties of the drug are due to the presence in its composition of natural fungicides and antibiotics secreted by the intestinal microflora of the earthworm during vermicultivation.

We were guided by the following methods when conducting laboratory and analytical studies: humus content according to Tyurin; pHKCL - ionometric. the content of P_2O_5 and K_2O according to Kirsanov. Grain quality analysis was carried out using standard methods: sampling. extraction of samples — GOST 13586.3-83. total nitrogen by the indophenol method — GOST 13496.4-93. crude protein. recalculated N total x 5.7; fall number - according to the Hagberg - Pertin method - GOST 27676-88. grain nature - GOST 10840-64. 1000 grain weight - GOST 10842-89. grain moisture - GOST 135-86.5-93. The specific activity of ^{137}Cs in the grain was determined on a measuring complex by the Gamma + USC (universal spectrometric complex) with Progress-200 software in Marinelli geometry.

The experimental data were mathematically processed by the method of analysis of variance. Energy assessment was carried out according to methodological developments (Nikiforov et al. 1995). The economic efficiency of winter rye cultivation technologies was calculated according to the methodology of the All-Russian Research Institute of Agricultural Economics on the basis of standard technological maps (Dmitrenko. 1988).

Results and its discussion.

Productivity is the most important integrating indicator of the degree of favorable external environment and plant development. The minimum yield of winter rye grain on average over the years of research was noted in the control variant (0.60 t / ha). which is typical for the natural fertility of the sandy soil of the experimental plot (Table 1).

The fertilizers used had a statistically significant effect on the value of this indicator. Thus. the use of litter manure of 80 t / ha in the third crop provided an increase of 0.29 t / ha in relation to the control. the organomineral fertilizer system increased the yield of winter rye grain to 1.42 t / ha. The increase in relation to control was 0.82 t / ha. The introduction of an equivalent amount of nutrients ($N_{140}P_{60}K_{120}$) in the mineral fertilizer system contributed to an increase in productivity by 3.1 times; the increase was 1.24 t / ha.

Table 1. Productivity and grain quality of winter rye. average for 2003-2013

Indicator Option	Productivity. t / ha	Mass of 1000 grains. g	Grain nature. g / l	Glassiness.%	The protein content.%	Amylogram height. ea.	Fall number. sec.	The specific activity of ^{137}Cs. Bq / kg
1. Control (without fertilizer)	0.60	35.8	653	15	11.8	626	185	84
2. Aftereffect of manure 80 t / ha	0.89	37.0	658	17	12.5	633	191	43
3. Aftereffect of manure 40 t / ha +$N_{70}P_{30}K_{60}$	1.42	37.5	671	17	12.7	633	193	33
4. $N_{70}P_{30}K_{60}$	1.34	37.1	665	17	12.5	633	193	29
5. $N_{140}P_{60}K_{120}$	1.84	38.9	677	18	12.9	637	196	28
6. $N_{210}P_{90}K_{180}$	1.58	37.7	684	18	13.1	637	198	29
7. Aftereffect of manure 40 t / ha +$N_{70}P_{30}K_{60}$+ pesticides	2.04	38.9	682	17	12.7	634	196	27
8. $N_{70}P_{30}K_{60}$+ pesticides	1.50	37.5	671	16	12.5	633	192	28
9. $N_{140}P_{60}K_{120}$+ pesticides	2.08	38.9	685	18	12.8	638	198	23
10. $N_{210}P_{90}K_{180}$+ pesticides	2.19	38.7	689	18	13.3	638	199	22
11. Aftereffect of manure 40 t / ha+$N_{70}P_{30}K_{60}$+ pesticides + humistim	2.47	38.9	696	18	12.8	637	202	17
12. $N_{70}P_{30}K_{60}$+ pesticides + humistim	2.01	39.3	699	18	12.7	636	200	16
13. $N_{140}P_{60}K_{120}$+ pesticides + humistim	2.63	40.0	700	19	13.0	639	205	15
14. $N_{210}P_{90}K_{180}$+ pesticides + humistim	2.51	39.8	698	19	13.3	640	206	15
15. HCP_{05}	0.21	1.5	8	3	0.28	5	6	5.2

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An increase in the dose of mineral fertilizer to $N_{210}P_{90}K_{180}$ did not lead to an increase in productivity. which is explained by the depressing effect of a high dose of NPK. especially with a deficit of soil moisture during the growing season. grain yield in this variant formed at the level of 1.58 t / ha.

The use of fertilizer in combination with chemical plant protection products increased the yield of winter rye by 0.90-1.59 t / ha compared with the control. with the highest background value of $N_{210}P_{90}K_{180}$ and pesticides. which is explained by a decrease in the degree of lodging and a decrease in the susceptibility of plants to diseases and pests. The highest increases (1.42-2.03 t / ha) were observed in the case of complex use of fertilizer. pesticides and humistim. Analysis of variance confirms the highest reliable effect of the complex interaction of fertilizers. pesticides and humistim. The maximum yield in the experiment was 2.63 t / ha using the $N_{140}P_{60}K_{120}$ mineral fertilizer system in combination with chemical plant protection products and a humistim biological product.

The minimum weight of 1000 grains of 35.8 g was noted in the control variant. The use of litter manure of 80 t / ha in the aftereffect and the $N_{70}P_{30}K_{60}$ mineral fertilizer system provided only a tendency to increase the value of this indicator. According to the organomineral and mineral fertilizer system $N_{140}P_{60}K_{120}$ and $N_{210}P_{90}K_{180}$. a significant increase in grain size by 1.7-3.1 g was noted in comparison with the control. The highest weight of 1000 grains of 38.9-40.0 g was formed with the combined use of fertilizer. chemical plant protection products and humistim biological product. which indicates the content of a large supply of reserve nutrients in the grain and the best technological indicators. since grain processing a significant part of the grain is represented by its most valuable part - endosperm.

The nature of winter rye grain ranged from 653 to 700 g / l with a minimum value of this indicator in the control. Under the influence of fertilizers. it increased by 1.0-4.7%. fertilizers and pesticides - by 2.8-5.5%. fertilizers and pesticides and humistim - by 6.6-7.2%.

The glassiness of winter rye grains varied from 15 to 19% according to the experimental variants. The use of $N_{140}P_{60}K_{120}$ and $N_{210}P_{90}K_{180}$ fertilizers both in pure form and in combination with pesticides had a significant effect on this indicator. The complex use of fertilizers. chemical plant protection products and humistim contributed to the increase of this indicator to 18-19%.

The protein content in the grain of winter rye varied from 11.8 to 13.3%. The use of fertilizer. both in the aftereffect and in direct action. provided a statistically significant increase in protein in winter rye grain. It should be noted that the protein content in winter rye grain increased under the influence of increasing doses in NPK. With the integrated use of chemicals in the experiment. the processes of synthesis and metabolism in plants were activated. which contributed to the strengthening of the photosynthetic activity of the leaf apparatus and its longer operation. which predetermined an increase in the protein content of winter rye grain.

The height of the amylogram according to the experimental variants ranged from 626-640 ea. The highest value is 637-640 e.a. noted in the case of the integrated use of fertilizers with pesticides and humistim. The state of the carbohydrate-amylase complex by the number of drops was in the range of 185–206 s with a minimum indicator in the control. High-quality bread is baked from grain with a falling number above 200 s (Malyavko. 2009; Sysuev et al. 2010; Ermolaeva et al. 2014). In our experiments. high-quality grain was formed in variants with the integrated use of intensification means.

The specific activity of ^{137}Cs in winter rye grain against the background of natural fertility (control) was 84 Bq / kg. with a standard of 70 Bq / kg. The use of fertilizer both with separate application and in combination with pesticides and humistim allowed us to produce normatively pure products with the content of ^{137}Cs of 1.95-5.60 times lower than in the control. The use of pesticides and a biological product of humistim against the background of the used fertilizer systems contributed to a maximum decrease in the concentration of ^{137}Cs in winter rye grain by 4.9-5.6 times. compared to the control. which occurred due to biological dilution due to increased yield. as well as due to additional introduction of potassium humates as a part of humistim.

Energy analysis indicates that the energy yield with the grain yield varied from 8.03 GJ / ha to 35.22 GJ / ha. that is. the range of variation of this indicator was 439%. The maximum was provided by the $N_{140}P_{60}K_{120}$ variant with

chemical plant protection products and humistim (Table 2).

As the doses of mineral fertilizers increased. energy consumption increased 1.87-3.45 times. mineral fertilizers and pesticides 2.1-3.7 times. the integrated use of intensification agents 2.2-3.7 times. compared to control.

The specific costs of total energy per 1 ton of main production or energy "cost" varied from 7.3 to 18.2 GJ / t. with a minimum indicator of the variant using an organomineral fertilizer system in combination with pesticides and humistim and a maximum of Fertilizer $N_{210}P_{90}K_{180}$.

An increase in energy or a net energy income of more than 10 GJ / ha ensured: the organomineral fertilizer system in combination with pesticides. the same fertilizer system in combination with pesticides and the humistim biological product. and the $N_{140}P_{60}K_{120}$ mineral fertilizer system in combination with chemical plant protection products and the humistim biological product. A negative increase in energy from 1 ha (loss) was noted in the control. as well as in the test variants with the use of $N_{210}P_{90}K_{180}$ both in combination with pesticides and without the use of chemical plant protection products.

The highest coefficient of energy efficiency of 0.59 and 0.83 is noted in the variants with the use of the organomineral fertilizer and pesticides system and this fertilizer system with the integrated use of intensification means.

Table 2. Energy and economic efficiency of winter rye cultivation

Option Indicator	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Productivity. t / ha	0.60	0.89	1.40	1.34	1.84	1.58	2.04	1.50	2.08	2.19	2.47	2.01	2.63	2.51
Received energy with the crop. GJ / ha	8.03	11.92	18.75	17.94	24.64	21.16	27.32	20.09	27.85	29.32	33.07	26.91	35.22	33.61
Energy expended. GJ / ha	8.34	8.56	15.60	15.51	22.36	28.74	17.16	16.88	23.84	30.47	18.09	17.36	24.35	31.06
Net energy income. GJ / ha	-0.31	3.36	3.15	2.43	2.28	-7.58	10.16	3.21	4.01	-1.15	14.98	9.55	10.87	2.55
Energy Cost GJ / t	13.90	9.62	11.14	11.57	12.15	18.19	8.41	11.25	11.46	13.91	7.32	8.64	9.26	12.37
Energy efficiency ratio	-0.04	0.39	0.20	0.16	0.10	-0.26	0.59	0.19	0.17	-0.04	0.83	0.55	0.45	0.08
Bioenergy sowing coefficient	0.96	1.39	1.20	1.16	1.10	0.74	1.59	1.19	1.17	0.96	1.83	1.55	1.45	1.08
Costs of winter rye production. thousan	2.84	2.96	3.94	3.81	6.51	6.96	7.51	6.61	8.69	11.97	7.95	8.11	10.31	12.38

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d rubles. / ha														
The cost of gross output thousand rubles / ha	3.73	5.52	8.69	8.31	11.41	9.80	12.66	9.31	12.90	13.58	15.32	12.47	16.32	15.58
Cost of 1 ton of grain thousand rubles	4.73	3.33	2.81	2.84	3.54	4.41	3.68	4.41	4.18	5.46	3.22	4.03	3.92	4.93
Net income. thousand rubles / ha	0.89	2.56	4.75	4.50	4.90	2.84	5.15	2.70	4.21	16.1	7.37	4.36	6.01	3.2
Profitability level. %	31.3	86.5	120.6	118.1	75.3	40.8	68.6	40.8	48.4	13.4	92.6	53.4	58.3	25.8

In the control. as well as in variants using high doses of mineral fertilizer ($N_{210}P_{90}K_{180}$). both in combination with pesticides and without protective measures. the coefficient of energy efficiency was negative.

A similar trend persists in determining the bioenergy sowing coefficient (BPC). which indicates how many times the energy accumulation by the crop exceeds energy costs and allows us to estimate the cost recovery of anthropogenic energy when cultivating winter rye. The bioenergy seeding coefficient in our studies varied from 0.74 to 1.83. This indicator was the smallest in the variant using $N_{210}P_{90}K_{180}$. and the variant with the organomineral fertilizer system in combination with pesticides and the biological product humistim had obvious advantages.

An economic analysis shows that. as a whole. the indisputable advantages of the experiment were the organomineral fertilizer system in combination with pesticides and humistim. where the net income was 7.37 thousand rubles / ha with a profitability level of 92.6%.

Conclusion

The results of studies conducted on technologically contaminated sod-podzolic sandy soil indicate that the use of fertilizer can increase the yield of winter rye grain by 0.29-1.24 t / ha. fertilizers and pesticides by 0.90-1.59 t / ha. fertilizers. pesticides and biological product humistim at 1.42-2.03 t / ha compared with the control. The highest value of this indicator (2.63 t / ha) is achieved against the background of the organomineral fertilizer system in combination with chemical plant protection products and the biological product humistim. The complex use of intensification means increased the weight of 1000 grains by 8.6-11.7%. the nature by 6.6-7.2%. the vitreous by 3-4%. the protein content by 1.0-1.5% relative to control. High baking indicators characterized the resulting grain - the height of the amylogram is 636-640 units. amylograph. drop number 200-206 s.

Fertilizers. both with separate application and in combination with chemical plant protection products and humistim. reduced the accumulation of ^{137}Cs in winter rye grain by 2.0–5.6 times as compared to the control. The maximum effect was noted in the $N_{140}P_{60}K_{120}$ and $N_{210}P_{90}K_{180}$ variants in combination with pesticides and humistim.

It is most economically and energetically profitable to cultivate winter rye against the background of an organomineral and mineral fertilizer system with medium doses of $N_{140}P_{60}K_{120}$ in combination with chemical plant protection products and humistim.

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